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Pre-Remedial Design Study
Port of Tacoma Industrial Yard
Hylebos Waterway
Commencement Bay
Tacoma, Washington

Volume I

Prepared by
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PRE-REMEDIAL DESIGN STUDY
PORT OF TACOMA INDUSTRIAL YARD
HYLEBOS WATERWAY
COMMENCEMENT BAY, WASHINGTON

1.0 EXECUTIVE SUMMARY

This report presents the results of the Pre-Remedial Design Study of the Port of Tacoma Industrial Yard property (Industrial Yard) located on the Hylebos Waterway in Tacoma, Washington. This study was performed in accordance with the Pre-Remedial Design Project Plans (Port, 1997) and subsequent revisions to these plans which incorporated Environmental Protection Agency (EPA) and Washington State Department of Ecology (Ecology) comments (Hart Crowser, 1997a). This work is being performed in parallel with the Pre-Remedial Design Studies in progress by the Hylebos Cleanup Committee (HCC) and the Occidental Chemical Corporation (Oxychem).

Pre-Remedial Design field activities, including a diver reconnaissance survey and surface and subsurface sediment sampling of the side slope and bank areas of the Industrial Yard, were performed in two phases of work between November 1997 and January 1998. Detailed descriptions and summaries of these field activities are presented in Appendix A of this report.

1.1 Sediment Chemical Analysis

Sediment quality was evaluated by comparing the sediment chemical data with the Sediment Quality Objectives (SQOs) established in the Commencement Bay Record of Decision (ROD). Comparisons to SQOs were quantified and prioritized through the use of exceedence statistics (frequency and magnitude of exceedence) to determine the sediment constituents of concern for the Industrial Yard.

Based on SQO exceedence statistics, the following were identified as key constituents of concern in the surface sediments of the Industrial Yard ranked in order of priority: phenanthrene, polychlorinated biphenyls (PCBs), zinc, fluoranthene, copper, hexachlorobutadiene, and dibenz(a,h)anthracene. The following were identified as constituents of concern in the subsurface sediments of the Industrial Yard ranked in order of priority: hexachlorobutadiene, PCBs, dibenz(a,h)anthracene, phenanthrene, zinc, and mercury. These key constituents contain the highest and most frequent enrichments of SQOs, and encompass lesser enrichments of lower priority chemicals. The key constituents therefore provide a focused list of surrogate chemicals that help to delineate remediation areas and volumes.

1.2 Site Physical Characterization and Testing

Site characterization and physical testing included an underwater diver survey, and laboratory testing of physical and conventional parameters, including grain size, total organic carbon, total solids, and Atterberg limits determination.

1.2.1 Diver Survey

A diver reconnaissance survey showed that the side slope areas of the Industrial Yard, including the underpier areas on the Hylebos Waterway side and the berthing areas between finger piers on the Commencement Bay side of the property are generally comprised of soft sediments, typically greater than 3 feet thick. With decreasing water depth, the soft side slope sediments thin above elevation -8 to 0 feet MLLW approaching the shoreline embankments. The embankments are constructed of large riprap which contains small discontinuous deposits of sand and gravel. Potential dredging obstructions observed by the diver include large scrap metal and debris, submerged logs, and pilings.

1.2.2 Grain Size

The average grain size of sediments decreases with distance from the shoreline embankment. The average composition of the bank sediments (between elevation 0 foot MLLW and top of bank, at approximately 18 feet MLLW) is slightly silty, gravelly SAND, typically composed of 16% gravel, 73% sand, 8% silt, and 3% clay. The average composition of side slope sediments (between elevation 0 foot MLLW and the Pierhead Line, at approximately -20 to -30 feet MLLW) is very sandy, clayey SILT, typically composed of 2% gravel, 32% sand, 47% silt, and 19% clay.

1.2.3 Conventionals

The TOC content of the Industrial Yard sediments ranged from 0.78 to 5.5 percent. The total solids content ranged from 44.3 to 85.0 percent, generally decreasing with water depth, commensurate with increasing fines content.

1.2.4 Sediment Stratigraphy

Based on a review of subsurface sediment core profiles, diver observations, grain size data, and site bathymetry, three distinct geologic units were identified at the Industrial Yard.

- **Side Slope Silt (Unit 1)** consists of soft, green to black, clayey, sandy SILT with shell, wood, and metallic fragments. This unit comprises most of the sediments in the upper 3 feet of the waterway side slope areas (between elevation 0 foot MLLW and the Pierhead Line, at approximately -20 to -30 feet MLLW).

- **Lower Bank Sand (Unit 2)** is characterized as a black, silty, gravelly SAND with shell, wood, and metallic fragments. This unit is found in the surficial sediments at the base of the riprap bank on both the Hylebos Waterway side and Commencement Bay side of the site, near elevation -5 to 0 feet MLLW.

- **Upper Bank Gravel (Unit 3)** is characterized as a rust brown, sandy GRAVEL. A majority of these deposits were observed to contain metallic debris. This unit is typical of isolated sedimentary deposits within the interstices of the riprap on the upper bank beneath Pier 25.

In addition, debris piles are exposed on the shoreline embankment near 0 feet MLLW on the Hylebos Waterway side of the site, and beneath Pier 24 on the Commencement Bay side. These deposits consist primarily of fused rusty metallic debris and cobbles. Three debris deposits were identified at the site, as shown on Figure 3-1.

1.3 Delineation of Areas and Volumes above SQO Criteria

1.3.1 Impacted Sediment Areas

Areas of the Industrial Yard with concentrations greater than Commencement Bay SQOs were delineated based on the distributions of key constituents. The key constituents identified in Section 1.1 encompass the exceedences of other lower ranked chemicals, and will therefore drive the remedial design. Practically the entirety of the bank and side slope areas at the Industrial Yard exceeded the SQOs for one or more chemicals. Copper and zinc contamination over the bank areas, and PAH contamination over the side slope areas, was pervasive throughout the site, ranging between 1 and 10 times the respective SQOs for these chemicals.

Several hot spots with more severe enrichments were also encountered. One hot spot contains hexachlorobenzene (HCBD) enrichments to thousands of times the SQO along the southeastern property boundary beneath Pier 25. The extent of this hot spot cannot be accurately mapped using available sediment data because data collected by Oxychem on this part of the Industrial Yard contained elevated detection limits for HCBD. However, elevated concentrations of HCBD and associated chlorinated compounds are known to be present in Area 5106 waste material. The HCBD enrichments observed at the Industrial Yard are similarly correlated with Area 5106 waste material, as this material is visually observed to extend approximately 340 feet north along the lower slope of Pier 25 from the former Oxychem property boundary (Conestoga-Rovers, 1998).

A second hot spot containing PCB enrichments between 10 and 100 times the SQO covers much of the central underpier area, and a third hot spot containing PCB enrichments between 4 and 24 times the SQO, with secondary enrichments of copper and zinc, occurs in the northwestern part of the underpier area near the corner of the peninsula.

1.3.2 Impacted Sediment Volumes

Sediment Management Areas (SMAs) were identified for areas of the Industrial Yard which contain sediments exceeding the SQO. The SMAs were delineated according to the magnitude and type of contaminant present. Identification of SMA boundaries also considered the appropriateness of applying a consistent remedial technology to an individual unit. Preliminary *in situ* volume estimates were performed for each SMA identified. These volume estimates are presented in Section 6.

As much as 15,000 CY of *in situ* sediment exceeds SQOs at the Industrial Yard. Nearly the entire volume of sediment is located below elevation 0 feet MLLW on the side slopes. Contamination is also located in isolated gravelly pockets in the riprap above elevation 0 feet MLLW. Approximately 1,000 CY of fused metal debris piles were also mapped.

2.0 INTRODUCTION

This document, prepared by Hart Crowser presents data generated during the Pre-Remedial Design Study of the bank and side slope areas the Port of Tacoma Industrial Yard property. A detailed description of the Industrial Yard is presented below. A vicinity map showing the location of the Industrial Yard site is shown on Figure 2-1, including the bank and side slope areas which are the focus of this Pre-Remedial Design Study.

2.1 Description of the Project Area

2.1.1 Property Location

The former Industrial Yard is located at 401 Alexander Avenue, and includes roughly 14 acres of uplands with adjoining intertidal and subtidal areas of the Hylebos Waterway and Commencement Bay (Figure 2-2). Although the property is now called the Earley Business Center, it will be referred to as the Industrial Yard in this report. The Industrial Yard is situated at the end of the peninsula between the Hylebos and Blair Waterways, and the submerged lands fall within the Commencement Bay Nearshore/Tideflat Superfund site. According to a verbal statement made by Allison Hiltner of EPA to the HCC, the boundary of the Hylebos Waterway problem area ends at the Army Reserve lease line which is located between Piers 23 and 24. This investigation is limited to the area inside of the Hylebos Waterway problem area (i.e., northeast of the Army Reserve lease line).

The portion of the Industrial Yard under investigation includes that formerly occupied by the AK-WA Shipyard (Gianotti Corporation); during 1997, however, the shipyard entered into bankruptcy and vacated the premises. This investigation also extends southeast along the Industrial Yard waterfront to the area currently occupied by Tyson Seafoods. Sediment quality sampling adjacent to Tyson Seafoods was collected by Oxychem and these data are incorporated into our analysis concurrently with this investigation (see Appendix E). To the southwest, these properties are bordered by the Army Reserve and other Industrial Yard tenants draining to the Blair Waterway and Commencement Bay. To the southeast, the Industrial Yard is bordered by the Pioneer Chlor Alkali chemical plant (formerly Occidental Chemical Corporation).

2.1.2 Site Description

As a lessee to the Port of Tacoma, Tyson Seafoods currently operates a support facility for vessel supplies staging and loading. Tyson also conducts minor vessel maintenance. Previous shipyard conversion and repair operations at the site by

AK-WA Giannotti were discontinued in the winter of 1996. The Tyson Seafoods office and former AK-WA shipyard shops were the primary buildings at the site during the sediment investigation (see Figure 2-2). Since completion of the investigation, the buildings within the former AK-WA lease area have been demolished as part of an expansion of the Tyson lease area. This area will be paved and used as a parking area for Tyson.

The site includes three piers supporting current and previous site operations. Pier 25 is an 1,800-foot-long and 90-foot-wide wooden structure along the Hylebos Waterway. Pier 25 and two other wooden finger piers, Pier 24 and Pier 23, extend into Commencement Bay from the terminus of the Blair/Hylebos peninsula. The piers are supported by wooden pilings which are in fair to good condition. Pier 23, within the Army Reserve leasehold, is not included in the study area.

The project area extends from the top of the riprap bank, near elevation 18 feet MLLW, to the toe of the channel side slope, more or less coincident with the Pierhead Line on the waterway side (Figure 2-2). The banks of the Industrial Yard slope steeply into the intertidal zone at typical angles of about 2 horizontal:1 vertical (2H:1V). The bank faces are heavily riprapped with rock to about 0 feet MLLW but contain localized pockets of sandy and gravelly sediment. On the waterway side, the slope continues to drop sharply to the Pierhead Line, coincident with the edge of the pier, at which point water depths (mudline elevation between -25 and -32 feet MLLW) flatten into the main channel of the waterway (see Figure 2-2). A similar topography is present on the Commencement Bay side of the site, where the steeply dipping side slope descends to similar water depths (mudline elevation between -28 and -32 feet MLLW) within 100 feet of the bank. Beyond this break in slope, the floor of the shipways is relatively flat.

2.1.3 Current Site Use Activities

Current site operations include support services for Tyson Seafood vessels which put-in for cleaning and removal of fish processing wastes. The vessels are also resupplied with provisions and undergo servicing as needed. Maintenance includes painting and repair jobs, machining, and parts cleaning. No abrasive blasting, above-deck painting, in-water hull work, refitting, or dry dock activities are conducted.

The Port is currently in the process of redeveloping the former AK-WA lease area. The buildings within the former AK-WA lease area (including Building 588) have been demolished, and the Port intends to repave the area and replace the existing stormdrain system.

2.1.4 Historical Site Use Activities

The Industrial Yard has a long history of shipyard and related operations beginning with Todd Shipyard, a U.S. Navy contractor in 1917. Early site buildings and a dock structure at the location of existing Pier 25 were torn down by 1936, and then rebuilt prior to World War II (see Figure 2-3; 1946 aerial photograph). Pier 25 and the two main site buildings were constructed in their present configuration at that time, and additional bank riprap and fill may have also been placed during this period.

During operation by Todd and the U.S. Navy (until 1960), the site was part of a larger shipyard which covered nearly 200 hundred acres of the Hylebos-Blair peninsula. Typical shipyard activities included construction and refitting of military vessels, with associated hull painting and abrasive blasting. Paint shops, metal working facilities, carpentry shops, chemical storage areas, and a boiler facility supported these operations. The configuration of several site buildings and other structures changed several times until the Navy's sale of the property to the Port of Tacoma in 1960 (see Figure 2-4; 1960 aerial photograph).

Between 1960 and 1984, Zidell Dismantling Corporation conducted ship salvage and metal scrapping. Waste petroleum, PCBs, and asbestos were generated from these activities for recycling, and large piles of debris or other stored materials are visible in aerial photographs from 1974 and 1979 (see Figures 2-5 and 2-6). Numerous other marine service and metal working operations were located at the site during this time period.

The AK-WA Shipyard operations began in 1986 and continued until the bankruptcy of Giannotti, the parent corporation, in 1997. AK-WA conducted intensive vessel conversion and maintenance on a floating dry dock between Pier 24 and Pier 25 as well as dockside repairs. Accumulated sandblast grit was cleaned from site catch basins on several occasions. Sandblast grit was observed in cracks and holes on the paved portion of the site during Hart Crowser's initial site walk on September 30, 1997. Chemical analyses of the grit residues from catch basin cleanout detected elevated concentrations of lead, copper, zinc, PCBs, and tributyltin (TBT). These grit residue samples were collected by AK-WA in response to NPDES and upland source control concerns from Ecology.

Documented releases of pollutants from historical site activities resulted in a number of administrative actions by Ecology. These included discharges of waste oil products to the waterway and NPDES permit violations associated with Zidell operations between 1969 and 1975. In 1989, AK-WA reported a spill of 3,000 gallons of diesel to the waterway, containing 2-butanone, xylene, and toluene. Also, copper, zinc, total suspended solids, and oil and grease concentrations in AK-WA storm water discharges often exceeded NPDES permit limits.

2.1.5 Adjacent Sites of Concern

Since 1929 Occidental Chemical Corporation (Oxychem; formerly Hooker Chemical) has operated a chlorinated chemical plant on the property southeast of the Industrial Yard. A new operator, Pioneer Chlor Alkali, took over operations in 1997. Migratory tetrachloroethylene, trichloroethylene, and related chlorinated compounds from the plant were detected in groundwater at the northeast corner of the Industrial Yard during the 1995 Phase II environmental assessment. A remedial program of groundwater treatment has been initiated by Oxychem. Sediments adjacent to the chemical plant contain high concentrations of chlorinated organic compounds (notably hexachlorobutadiene, hexachlorobenzene, and vinyl chloride). Because of their increased potential for causing toxicity and leaching to the waterway, the Hylebos Cleanup Committee has determined that these sediments—designated "Area 5106"—warrant special investigation.

2.2 Purpose and Scope of the Pre-Remedial Design Study

The work presented in this report is being performed in parallel with Pre-Remedial Design Studies in progress by the Hylebos Cleanup Committee (HCC) and the Occidental Chemical Corporation (Oxychem), which provide data coverage in the Industrial Yard, the adjacent deeper channel areas of the Hylebos Waterway, and the bank and side slope areas adjacent to Tyson Seafoods, respectively. Similar to the other studies mentioned, this work is subject to the terms of EPA's Record of Decision (ROD) for the Commencement Bay Nearshore/Tideflats Superfund Site (EPA, 1989), as well as the Administrative Order on Consent (AOC) and Statement of Work (SOW) for the Pre-Remedial Design of the Hylebos Waterway (EPA, 1993).

The data from this investigation were acquired to characterize the bank and side slope sediments on the Hylebos Waterway side and the bank sediments on the Commencement Bay side of the Industrial Yard study area. Sediment chemical, physical, and geological data presented in this report serve as the basis for evaluating the feasibility of remedial alternatives and selecting a remedial design for the Industrial Yard. This Pre-Remedial Design Study was performed in accordance with the Ecology- and EPA-reviewed Pre-Remedial Design Study Project Plans (Port of Tacoma, 1997) and final revisions to the plans which incorporated EPA and Ecology comments (Hart Crowser, 1997a).

The sampling, analysis, survey, and data evaluation efforts conducted during the Pre-Remedial Design Study were designed to meet the following objectives:

- Assess the physical and chemical characteristics of bank and side slope sediments in the Industrial Yard study area, to the extent necessary to develop a remedial alternative;

- Estimate the volume of impacted sediments at the Industrial Yard site; and

- Delineate Sediment Management Areas (SMAs) based on sediment testing results over which a consistent remedial technology may be applied.

The delineation of SMAs is based on chemical measurements (e.g., magnitude of exceedence above regulatory criteria) as well as physical and geographical constraints (e.g., water depth, navigational requirements, presence of structures or obstructions, etc.).

To achieve the project objectives, sediment samples were collected at the locations shown on Figure 2-2 and submitted for physical and chemical testing. The acquisition of these data is ultimately intended to support the evaluation and selection of a preferred remedial alternative for the site—more specifically, an alternative consistent with the Commencement Bay ROD and other CERCLA requirements, the HCC's approach to remediation of channel areas, and, to the extent possible, the development goals of the Port.

2.3 Organization of Report

This report is comprised of the following sections:

- **1.0 EXECUTIVE SUMMARY**;
- **2.0 INTRODUCTION**;
- **3.0 SITE CHARACTERIZATION AND PHYSICAL TESTING**;
- **4.0 SEDIMENT CHEMICAL ANALYSIS**;
- **5.0 NATURE AND EXTENT OF CONTAMINATION**;
- **6.0 SEDIMENT MANAGEMENT AREAS**; and
- **7.0 REFERENCES**.

Tables and figures are included at the end of each section and numbered in accordance with their respective sections.

This report is supplemented by four appendices which provide the detailed procedures and data summaries of sampling, analysis, testing, and surveying activities for the Industrial Yard Pre-Remedial Design Study. The appendices include the following:

APPENDIX A - FIELD ACTIVITIES AND METHODS
APPENDIX B - DATA VALIDATION SUMMARY
APPENDIX C - SEDIMENT CHARACTERIZATION AND PHYSICAL TESTING
APPENDIX D - LABORATORY CERTIFICATES OF ANALYSIS, ANALYTICAL RESOURCES, INC. AND COLUMBIA ANALYTICAL SERVICES, INC.
APPENDIX E - FIELD ACTIVITIES AND DATA REPORT EMBANKMENT BENEATH PIER 25 CONESTOGA-ROVERS & ASSOCIATES

2.4 Summary of Previous Investigations

Existing sediment quality data have been compiled by the HCC and other studies which provide characterization of subtidal and intertidal sediments and source materials on or adjacent to the Industrial Yard, including the following:

- Natural Resource Damage Assessment Sediment Survey (National Oceanic and Atmospheric Administration [NOAA] 1995);
- Sediment Data Evaluation Report for the 401 Alexander Avenue Property (Roy F. Weston, 1996);
- Final Sampling and Analysis Report, Watercraft Support Maintenance Center, Pier 23 (Pacific Western Services, 1995); and
- Industrial Yard Sediment Sampling Results (Port of Tacoma, 1994).

A complete listing of analytical results for the existing project database is provided in Appendix D of the Pre-Remedial Design Study Work Plan for the Industrial Yard (Port, 1997). Historical sample locations for the Industrial Yard are shown on Figure 2-7.

Additionally, a concurrent sediment study to this work in the Industrial Yard was performed by Oxychem. Because this work was performed at the same time as the Port's investigation and similar sampling and analytical methods were used, the results of the Oxychem study are provided and discussed in sections of this report. The data report resulting from the Oxychem study is presented in Appendix E.

2.4.1 Existing Data Quality

The data quality of the environmental studies cited above were qualitatively ranked to assess the general representativeness and suitability of these studies for use in Pre-Remedial Design. Based on adherence to EPA-established protocols for sampling, laboratory analysis, QA/QC, and data validation, an overall data quality ranking of A (highest) to C (lowest) was assigned. The HCC and Weston (1996) data have been fully validated consistent with CERCLA standards; these data are designated A quality and are acceptable without limitations for use.

The Pacific Western (1995) and Port of Tacoma (1994) data are designated B quality; these data were evidently acquired using standard sampling and analytical QA/QC protocols, but the data have either not been validated or the validation reports are not available. These data are acceptable for use in mapping the nature and extent of contamination.

Because of comparability and QC concerns raised by the HCC, chemical analyses performed by the Hylebos Trustees (NOAA, 1995) were designated C quality, and these analyses were excluded from the project database. The NOAA results indicate analytical bias and were evaluated using non-standard analytical methodologies and QA/QC protocols. The QC issues associated with the Trustee data are discussed in more detail in the HCC Round 1 Data Report (Striplin et al., 1997). Some of the Trustee sampling locations were reoccupied and analyzed for selected parameters by the HCC; these results are included in the project database.

2.4.2 Intertidal Sediment Samples

Intertidal sediment samples collected from the Industrial Yard included HCC samples 5201I, 5202I, 5203I, and 5215I, and Port of Tacoma samples HYL-1, HYL-2, and HYL-4. The Port samples (HYL-1, HYL-2, and HYL-4) were located around a mounded metallic deposit under Pier 25; the deposit itself (designated source material) was also sampled by the Port (HYL-3). HCC sample PIY-1 was also collected in sediment at the base of this same metallic source material. HCC sample 5205I was collected along the adjacent bank area at the Pioneer Chlor Alkali plant. Weston sample HYBL1, and Pacific Western samples TF-01 through TF-03 were collected from adjacent bank areas near Pier 23 on the Army Reserve lease area, outside of the Hylebos Waterway problem area.

The HCC, Weston, and Port of Tacoma samples were surface samples collected from the upper 10 cm or shallower, whereas the Pacific Western samples were collected from the upper 20 cm of sediment. The HCC and Weston samples were composited using two to eight locations along the bank intervals sampled. The Port of Tacoma and Pacific Western samples were collected from discrete locations and were not composited.

Laboratory analyses for the HCC, Weston, and Port of Tacoma samples covered a wide range of organic, inorganic, and conventional constituents. The Pacific Western samples were submitted only for analyses of total metals. SQO chemical criteria were exceeded for metals, PCBs, and semivolatile compounds, including a number of chlorinated compounds and polycyclic aromatic hydrocarbon (PAH) compounds, as discussed below.

Metals. For on-site samples, the most prevalent metal exceedences were for arsenic, cadmium, copper, lead, mercury, and zinc. The detected concentrations of these metals ranged up to 96 mg/kg arsenic, 8.5 mg/kg cadmium, 2,030 mg/kg copper, 618 mg/kg lead, 2.8 mg/kg mercury, and 2,260 mg/kg zinc in samples HYL-1, HYL-1, 5201I, 5203I, HYL-2, and 5202I, respectively. These maximum detections equate to SQO enrichment ratios of 1.7 for arsenic, 1.7 for cadmium, 5.2 for copper, 1.4 for lead, 4.8 for mercury, and 5.5 for zinc. Nickel and silver exhibited isolated (one sample in nine) and marginal SQO exceedences (enrichment ratios less than 2).

Elevated cadmium, copper, and mercury concentrations were also detected in an intertidal sediment sample located off site (to the west) on the Blair Waterway side of Pier 23. The maximum detected concentrations of these metals were 9.8, 480, and 10 mg/kg, respectively, in sample TF-01 (Pacific Western Services, 1995). The resulting SQO enrichment ratios were 1.9 for cadmium, 1.2 for copper, and 16.9 for mercury.

Several intertidal samples collected by the HCC were analyzed for tributyltin (TBT) in both bulk sediment and pore water matrices. The highest bulk sediment concentration (2,314 µg/kg) was detected in sample 5201I. However, none of the pore water TBT analyses (the highest being 0.032 µg/L in sample 5202I) exceeded the lower screening level for TBT (0.05 µg/L), indicating that the TBT is not bioavailable at toxic concentrations (Weston, 1996).

PCBs. PCB concentrations exceeding the SQO (300 µg/kg) were detected in samples 5203I and PIY-1 from the Industrial Yard project area. The PCB exceedence for sample 5203I was extremely high, with a concentration of 24,000 µg/kg, and a corresponding enrichment factor of 53.3. Sample PIY-1 contained a concentration of 760 µg/kg and an enrichment of 2.5 times the SQOs. In adjacent intertidal sample 5205I, PCBs were detected at a concentration of 350 µg/kg, slightly in excess of the SQO concentration.

SVOCs. Concentrations of several chlorinated benzene compounds exceeded SQO criteria in on-site sample 5203I. These compounds included 1,2,4-trichlorobenzene (1,100 µg/kg), 1,3-dichlorobenzene (950 µg/kg), and 1,4-dichlorobenzene (730 µg/kg). SQO enrichment ratios for these compounds were 21.6, 5.6, and 6.6, respectively. Concentrations of hexachlorobutadiene also exceeded its SQO criteria in sample 5203I (16 µg/kg; enrichment factor of 1.5).

A number of PAH compounds were detected at concentrations exceeding their SQO criteria in several of the intertidal samples. Concentrations of total LPAHs and HPAHs reached 18,000 and 65,000 µg/kg, respectively, and enrichment ratios of individual PAH compounds were as high as 6.1 (phenanthrene in HYL-4). The most notable PAH enrichments occurred near the mounded metallic deposit (HYL-series samples) and on the bay shore of the former AK-WA site (sample 5215I). Bis(2-ethylhexyl)phthalate and dibenzofuran also exceeded their respective SQOs, but at relatively low enrichment ratios (i.e., less than 2).

In off-site samples, elevated hexachlorobutadiene and hexachlorobenzene concentrations were detected in sample 5205I from the adjacent Pioneer Chlor Alkali parcel (formerly Oxychem), with enrichment ratios of 74.5 and 2.9, respectively. Elevated dibenz(a,h)anthracene (270 µg/kg) was also detected in this sample (SQO enrichment factor of 1.2). One minor SQO exceedence of the volatile organic compound tetrachloroethene was also detected in this sample (85 µg/kg at 1.5 times the SQO).

Bioassays. The HCC intertidal samples (5201I, 5202I, and 5215I) from the Industrial Yard that were submitted for bioassay testing exhibited significant toxic effects in laboratory organisms. Each of these three samples resulted in at least one MCUL failure (the more severe of the SMS biological criteria), and sample 5215I had two MCUL failures in the suite of three bioassays. Benthic abundance was not tested in these samples. Given the severity of the bioassay test responses in the intertidal areas of the Industrial Yard, no additional bioassay testing was pursued in the Pre-Remedial Design Study.

2.4.3 Subtidal Sediment Samples

Subtidal samples collected in the vicinity of the Industrial Yard include HCC samples 5101 and 5105, and Trustee (NOAA) samples HY-02 through HY-06. The HCC resampled the NOAA locations for a select group of analytes (HCC-HY-XX designations); it is these data that are summarized here. Samples analyzed from HCC locations 5101 and 5105 include a surface sediment sample designated "S" (0 to 10 cm depth), and collocated core sections designated "A" (0 to 4 feet), and "B" (4 to 8 feet).

Metals. Mercury was exceeded in one of fifteen analyses, at 2.2 times its SQO (1.3 mg/kg in sample 5101A).

A pore water TBT analysis from a subtidal sample offshore from the former AK-WA site (0.012 µg/L in sample HCC-HY-03) did not exceed the pore water TBT screening level (0.05 µg/L), indicating that the TBT is not bioavailable at toxic concentrations.

SVOCs. The most prevalent exceedences of SQO criteria in the subtidal sediment samples were for hexachlorobenzene and hexachlorobutadiene; the SQOs for these compounds were exceeded in 42 and 73 percent of the samples with adequate detection limits, respectively (Table 4-3B). Their maximum concentrations were 53 µg/kg hexachlorobenzene in sample 5103A (enrichment factor of 2.4), and 52J µg/kg hexachlorobutadiene in sample 5101A (enrichment factor of 4.7).

A number of other semivolatile/PAH compounds marginally exceeded their SQO criteria (enrichment ratios less than 2) in a single subtidal sample—these include 1,4-dichlorobenzene, anthracene, fluoranthene, phenanthrene, and phenol.

Bioassays. Samples from locations HY-02/HCC-HY-02 and HY-04/HCC-HY-04 (combined HCC and NOAA Trustee data) exhibited significant biological effects. Both locations failed the echinoderm larval bioassay at the SQS level. HCC-HY-02 also failed the benthic abundance test at the SQS level, and HCC-HY-04 failed the benthic abundance test at the more severe MCUL level. Given the severity of the bioassay test responses in the subtidal areas offshore from the Industrial Yard, additional bioassay testing was not pursued in this Pre-Remedial Design Study.

2.4.4 Source Material Sample

Granular material from within the metallic debris beneath Pier 25 was sampled by the Port (sample HYL-3). Elevated concentrations of arsenic (1.2), cadmium (2.9), copper (2.4), lead (6.7), zinc (5.9), and PAHs (maximum anthracene at 3.2) exceeded their respective SQO criteria (enrichment ratios provided in parentheses).

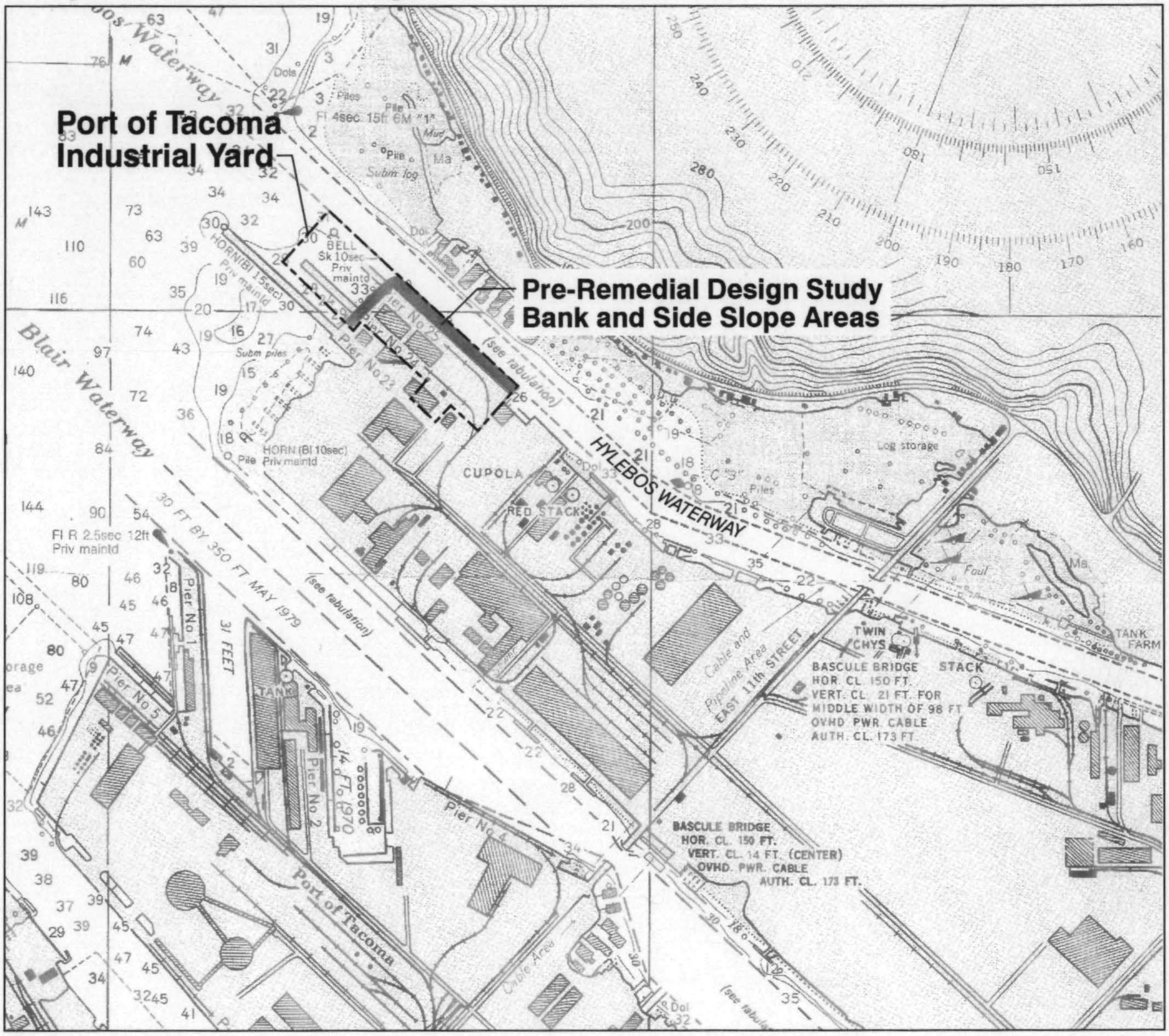
2.5 Potential Historical Sources

Known historical activities suggest a number of potential pollutant sources which are consistent with the observed distribution of chemical constituents in intertidal and subtidal sediments. Historical shipyard, metal working, salvage, and scrapping operations at the Industrial Yard are a possible source of elevated concentrations of metals and PCBs in sediment. Elevated copper, lead, zinc, and PCBs were associated with sandblast grit residues from catch basin cleanout at the former AK-WA shipyard. These chemicals were detected at elevated concentrations in sediment sampled at the base of a metallic deposit beneath Pier 25 (HCC sample PIY-1). TBT, arsenic, and mercury are additional constituents commonly associated with historical sandblast grit (and paint chips contained in the spent grit) in the shipyard industry. Copper, zinc, and historically TBT and mercury are or have been common antifouling agents (biocides) added to marine paint.

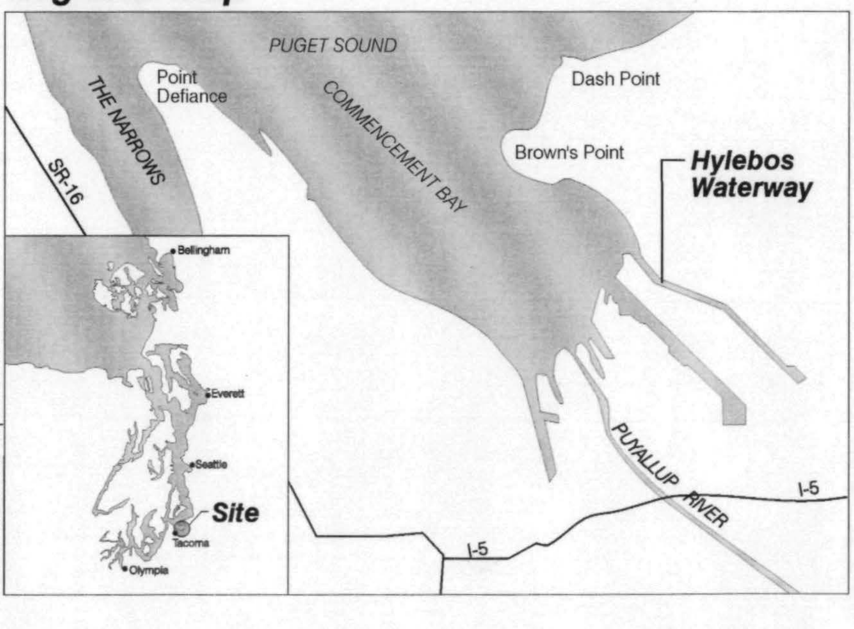
Shipyard support activities, metal working operations, waste oil spills, coal tar-based marine paints, or leaching from treated pier pilings are possible sources of elevated PAHs in sediments adjacent to the Industrial Yard.

Historical discharges from the Oxychem Chemical plant are the suspected source of hexachlorobutadiene and hexachlorobenzene in sediments because these compounds are key indicators of chlorinated hydrocarbon production. Elevated concentrations of these and associated chlorinated compounds are typical of Area 5106 and of channel and side slope areas in the vicinity of the former Oxychem plant.

Project Location Map



Regional Map



Not to Scale

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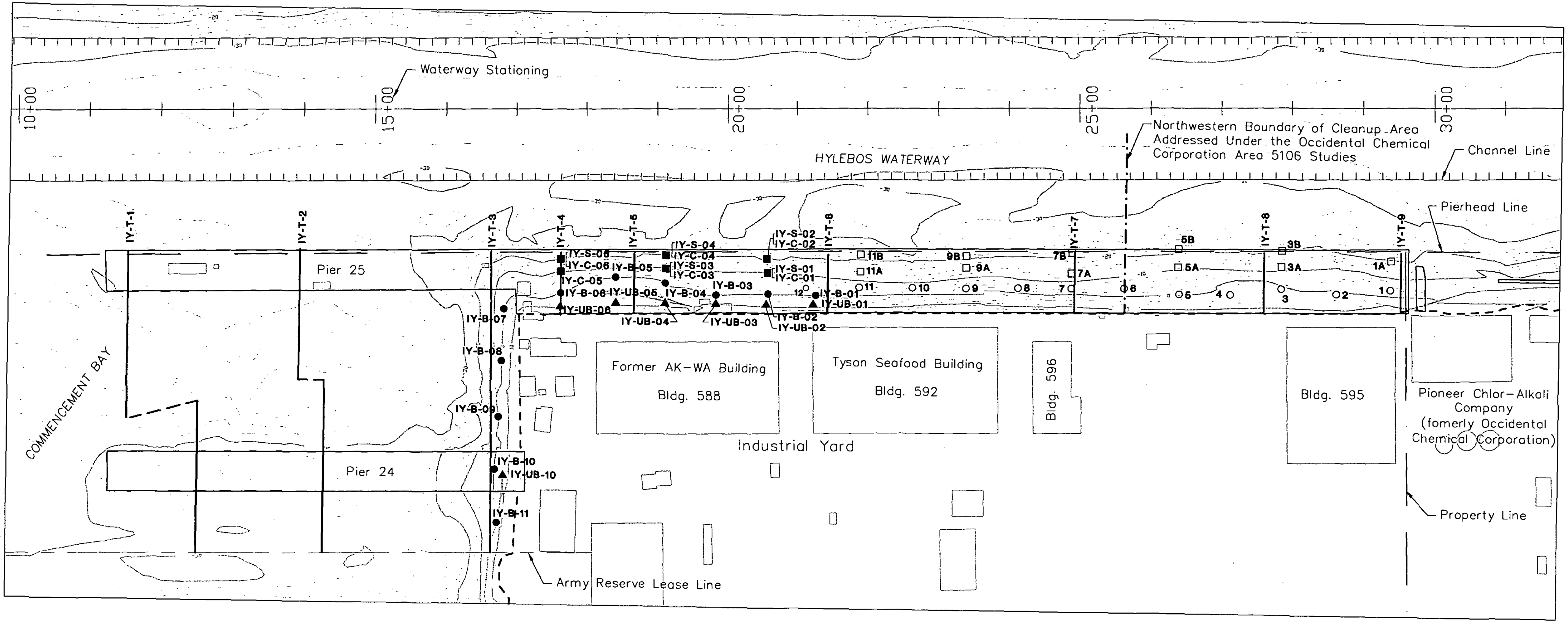
Figure 2-1

Confirmed Sample Location Plan
Port of Tacoma Industrial Yard



Port of Tacoma, 1998
Sample Location, Number, and Type (Depth)

● IY-B-01 Bank Sample (0 to 10 cm)

▲ IY-UB-01 Upper Bank (0 to 10 cm)

■ IY-S-01 / IY-C-01 Side Slope Surface Sample (0 to 10 cm) Collocated Subsurface Sample (0 to 3 ft)

IY-T-1 Approximate Diver Survey Transect Line Location and Number

Occidental Chemical Corporation, 1998
Sample Location, Number, and Type (Depth)

○ 10 Bank Sample (0 to 10 cm)

□ 7A Side Slope Surface Sample (0 to 10 cm) with Collocated Subsurface Sample (0 to 3 ft)

CVD 10/30/98 1=150 xref=Base and Contour wdsk.pc2
48580326

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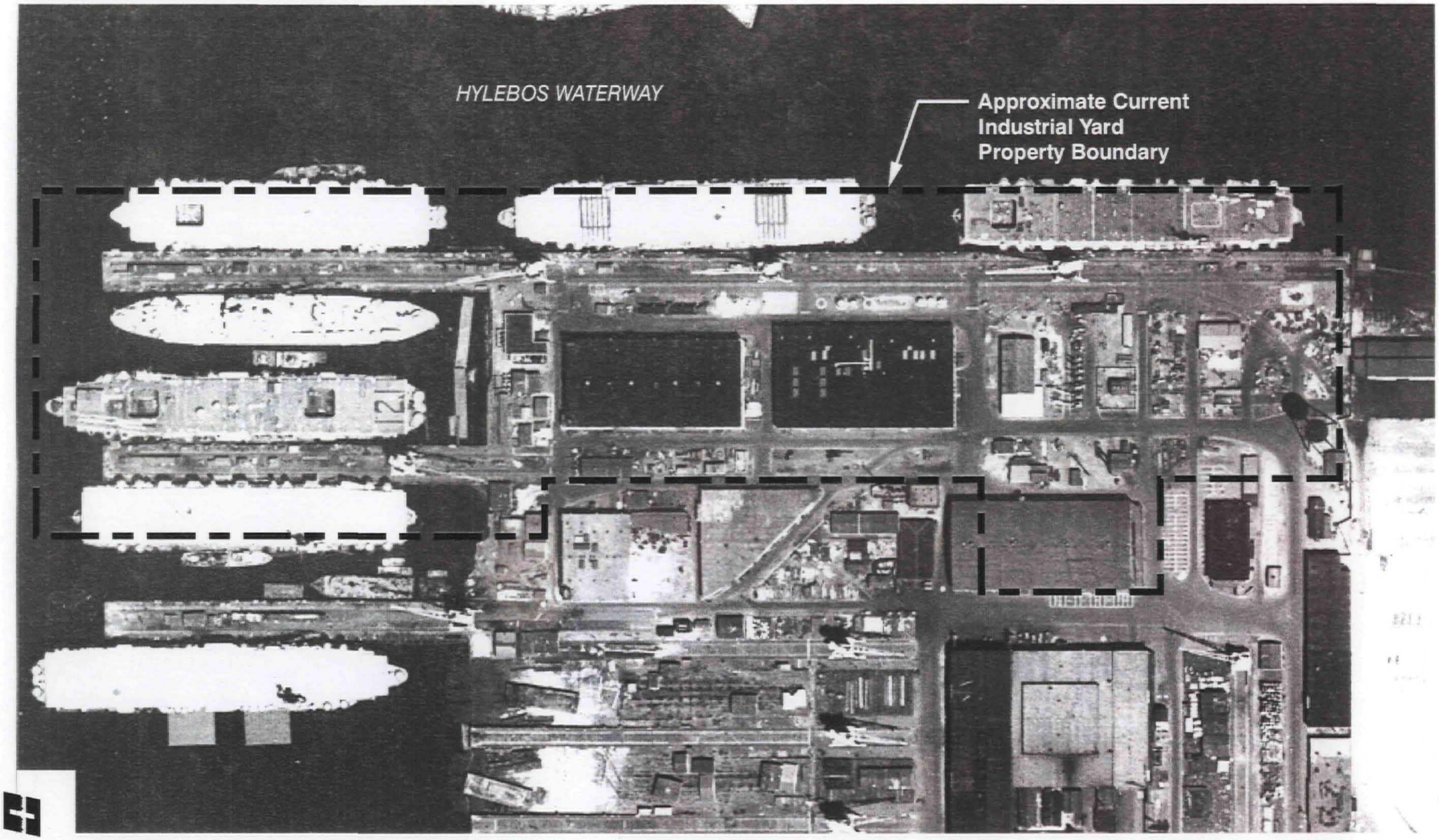
J-4858-03 10/98
Figure 2-2

1946 Aerial Photograph
Port Industrial Yard Area



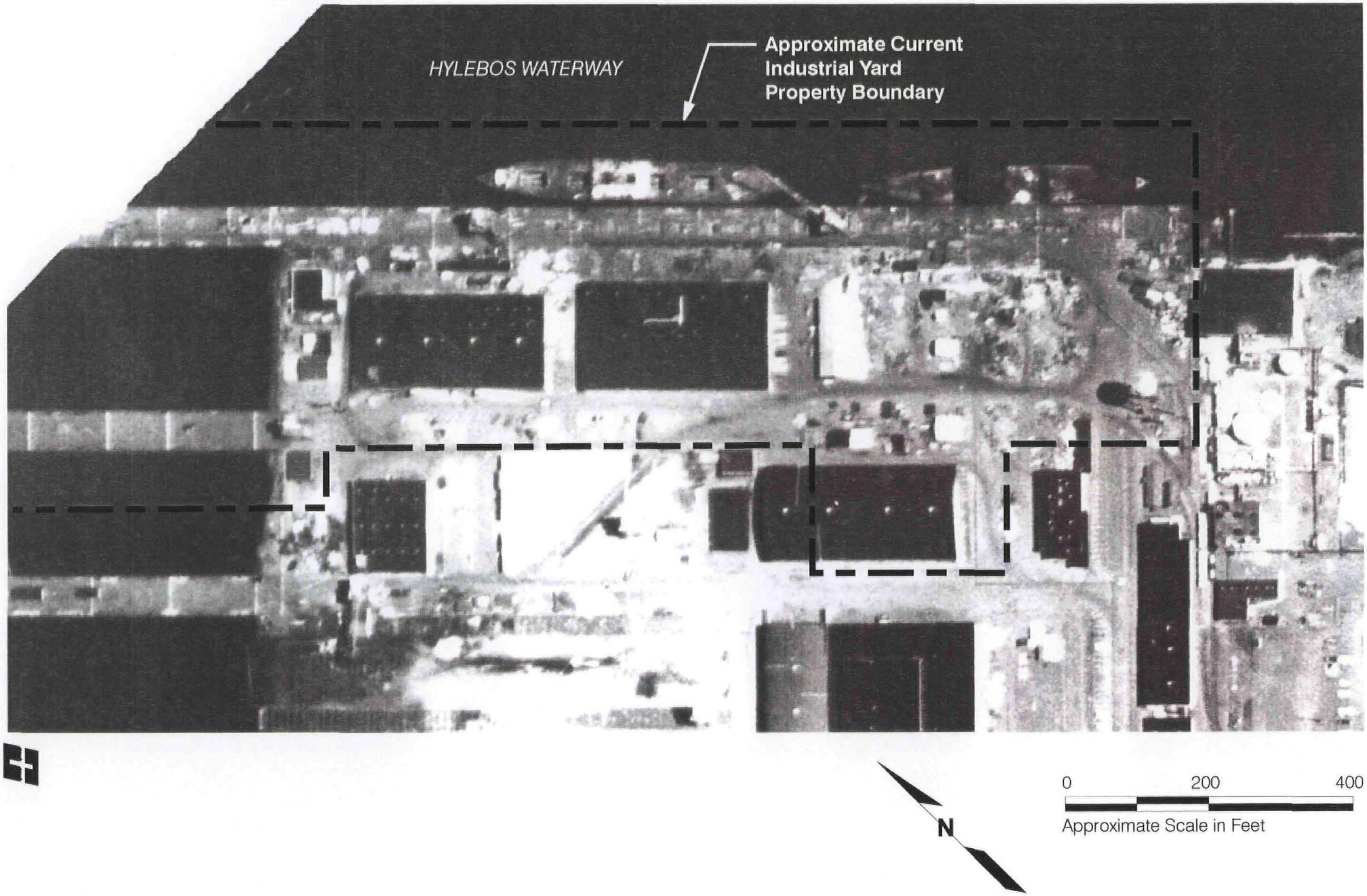
N

0 200 400
Approximate Scale in Feet

Corel\485803\1946Aerial

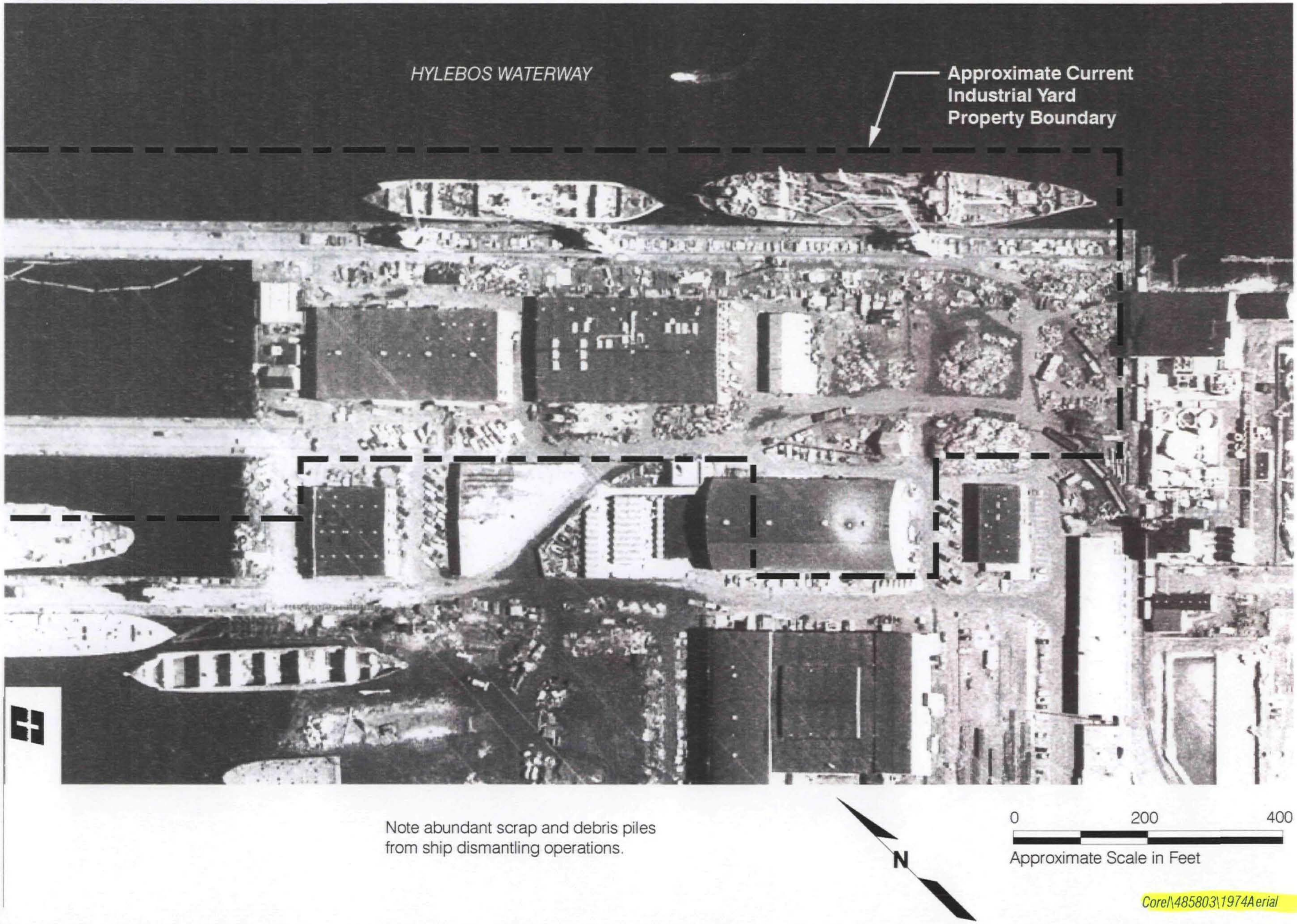
HARTCROWSER
J-4858-03 10/98
Figure 2-3

1960 Aerial Photograph
Port Industrial Yard Area



Corel\485803\1960Aerial

1974 Aerial Photograph
Port Industrial Yard Area

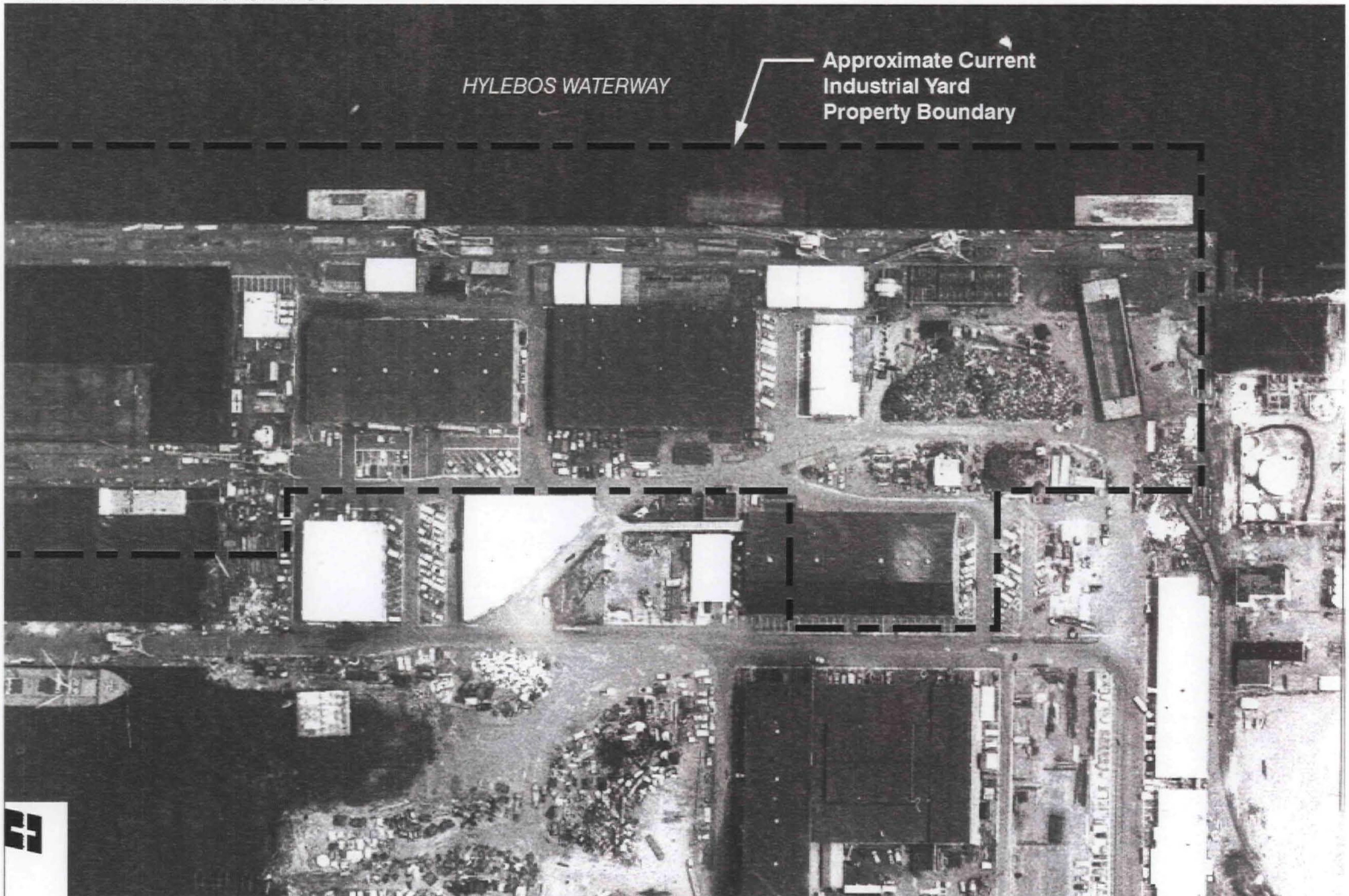


Note abundant scrap and debris piles
from ship dismantling operations.

Corel\485803\1974Aerial

HARTCROWSER
J-4858-03 10/98
Figure 2-5

1979 Aerial Photograph
Port Industrial Yard Area



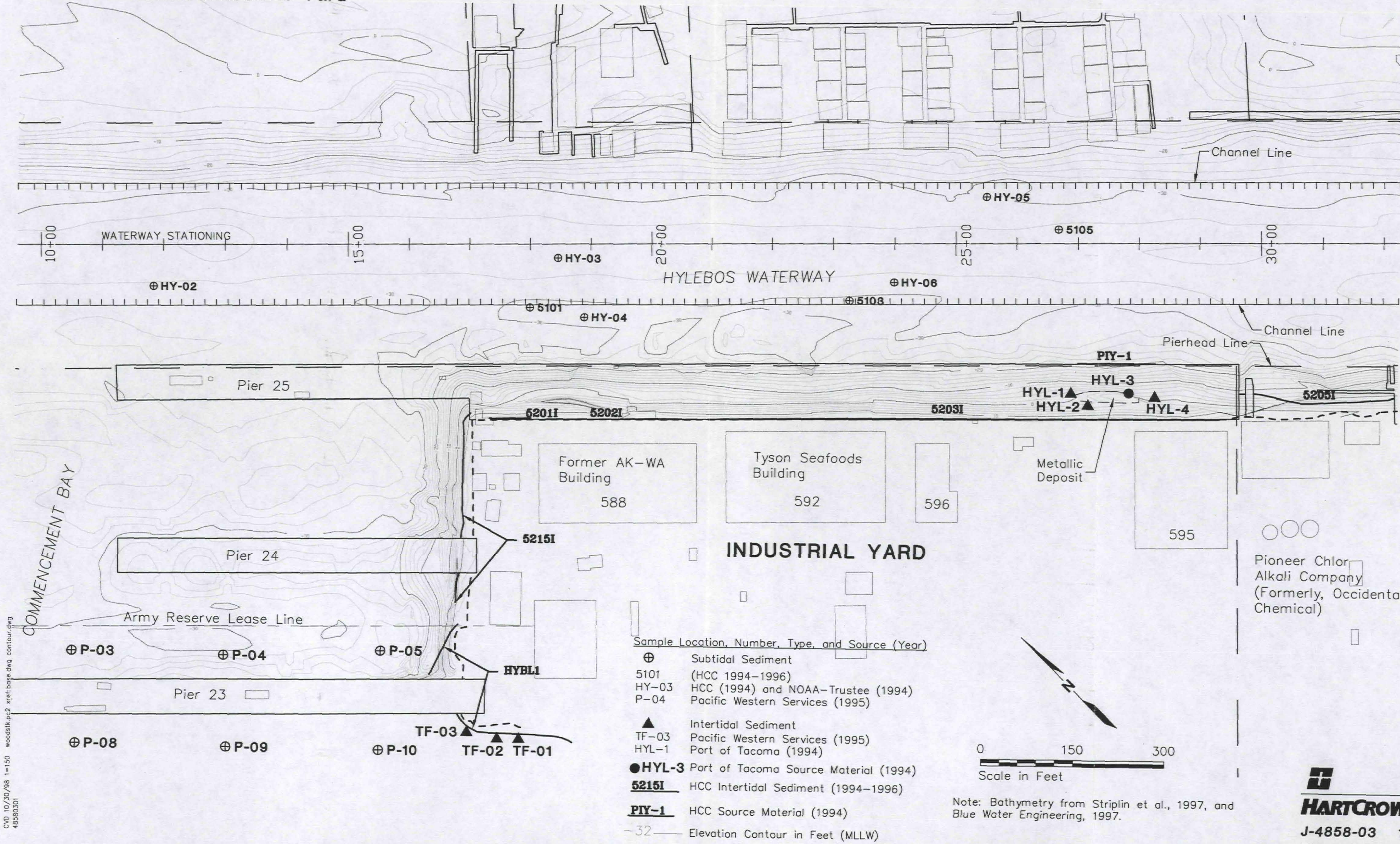
Note scrap and debris piles in SE part of yard and other locations.

HARTCROWSER
J-4858-03 10/98
Figure 2-6

Corel\485803\1979Aerial

Historical Sample Location Plan

Port of Tacoma Industrial Yard



Note: Bathymetry from Striplin et al., 1997, and Blue Water Engineering, 1997.

HARTCROWSER

J-4858-03 10/98

Figure 2-7

CVD 10/30/98 1=150 woodstk.pc2 xref:base.dwg contour.dwg 48580301

3.0 SITE CHARACTERIZATION AND PHYSICAL TESTING

This section describes the results of the site characterization and physical testing performed as part of the Pre-Remedial Design Study for the Industrial Yard. The site characterization consisted of shoreline and underwater diver reconnaissance surveys, and geologic descriptions of sediment samples and cores. Physical testing of Industrial Yard sediments consisted of laboratory analysis for conventional and physical parameters, including total organic carbon, grain size, and total solids content. Sediment descriptions and core logs are provided in Appendix A; physical testing methods and results are provided in Appendix C.

3.1 Site Reconnaissance Surveys

3.1.1 Shoreline Survey

On January 8, and again on May 26, 1998, Hart Crowser personnel performed a site walk of the Industrial Yard bank at low tide to observe sediment conditions in and at the base of the riprap bank. On January 8, Hart Crowser personnel were accompanied by representatives from the Port, Oxychem, and the EPA (Ken Marcy) to assess sediment conditions on the upper bank, identify areas that could be sampled within the riprap, and to coordinate field investigations between the Port and Oxychem at the Industrial Yard.

Isolated, gravelly patches of sediment, only several feet in dimension, were observed within the riprap bank beneath Pier 25 on the waterway side of the Industrial Yard, and sufficient material was present to collect upper bank samples. Clean riprap with no sediment patches, except locally beneath Pier 24, were observed on the Bay side of the Industrial Yard, and only one upper bank sample (IY-UB-10) could be obtained along this part of the shoreline. Continuous sediment coverage was observed on a low-tide bench beginning at the base of the riprap near elevation 0 feet MLLW, and continuing out onto the side slope areas. The May 26 survey was conducted on a more extreme low tide, allowing observation and measurement of nearshore debris piles comprised of cobbles, brick, wire, and fused pieces of scrap metal (see Figure 3-1 and Section 3.2.2).

3.1.2 Underwater Diver Survey

The underwater reconnaissance survey of the Industrial Yard was performed along the nine transects (IY-T-1 through IY-T-9) shown on Figure 2.2. Transects IY-T-1 through IY-Y-3 extend from the pier face of Pier 25, near elevation -30 feet MLLW, to the Army Reserve Lease Line on the southwest side of Pier 24, near elevation -30 feet MLLW (Figure 3-1). IY-T4 through IY-T-9 extend from the pier face of Pier 25, near elevation -25 feet MLLW to the underpier embankment.

The objective of this survey was to describe and document the general condition of the surface and near-surface sediments in the Industrial Yard, especially as these conditions may contribute to remediation hazards. Along each transect the diver documented the site condition using both a video camera and by transmitting visual descriptions via intercom to the field crew on board the survey vessel. The diver also estimated the thickness of recent sediments using a "T" probe. Results of the diver reconnaissance survey are summarized on Figure 3-1.

The diver reconnaissance survey showed that surface sediments along the side slopes are generally comprised of soft material, occasionally intermixed with small rocks, gravel, pipes, and man-made debris such as cables, rope, and metal debris. Surficial wood debris ranging from tree branches to submerged pilings is abundant throughout the study area. The boundary of the shoreline armoring (riprap) was typically encountered near elevation 0 feet MLLW on the Hylebos Waterway side of the bank, but locally extended to elevation -10 feet MLLW on the Commencement Bay side of the bank. Shoreline armoring consists primarily of riprap with large (> 2-foot-diameter) boulders; however, block and debris materials locally contribute to the embankment armoring on the Hylebos Waterway side of the Industrial Yard.

Along the side slope and in the deeper water areas, there were a limited number of features identified that could potentially pose a hazard or impediment to dredging or other waterfront construction activities. Scattered logs and wood debris were observed in deeper water (below elevation -20 feet MLLW) under Pier 24 on transect IY-T-1 and between elevations 0 and -10 feet MLLW along transects IY-T-3, IY-T-4, and IY-T-7. Submerged piles were observed near elevation -10 feet MLLW on transect IY-T-4. Pipes, cables, and metal debris were observed in the former drydock area (below -20 feet MLLW) between Piers 24 and 25, under Pier 24 on transect IY-T-1, on the upper bank (near elevation 0 feet MLLW) on transect IY-T-3, and protruding through the sediment surface (near elevation -10 feet MLLW) along transect IY-T-6.

3.1.3 Sediment Thickness Survey

The Industrial Yard sediment thickness, as determined by diver probing, is shown on Figure 3-1. In deeper water, including the lower side slope areas on the Hylebos Waterway side, and in the outer part of the berthing area on the Commencement Bay side, sediment thickness was generally observed to be greater than 3 feet. Sediment thickness decreased shoreward toward the riprap bank. Above 0 feet MLLW, sediments were typically characterized by probe penetration of less than 1 foot and riprap was usually visible. The limited pockets of sediment observed within the riprap on the embankment were discontinuous and unmappable, and without significant thickness. Localized areas of hard substrate were also encountered in the footings beneath Pier 24 and Pier 25.

3.2 Subsurface Stratigraphy

The characterization of the stratigraphy of the Industrial Yard is based on field sediment descriptions, grain size testing, sediment core logs, and other observations made during the Pre-Remedial Design Study. Subsurface explorations of the Industrial Yard consisted of six sediment cores approximately 3 feet in depth. The locations of the subsurface cores (IY-C-01 through IY-C-06) are shown on Figure 3-2. Interpretive geologic logs of these core sections are presented in Appendix A. Field descriptions were confirmed with laboratory grain size analysis, as described in Section 3.3. A location plan for geologic cross sections through the Industrial Yard is presented on Figure 3-2. Three generalized geological cross sections of the site are presented on Figure 3-3.

3.2.1 Sedimentary Textures

The sedimentary textures observed on the side slope area of the Industrial Yard are likely a function of the energy of the depositional environment (e.g., intensity of wave and tidal action). The average grain size of the sediments generally decreases toward deeper water and away from the shore. Higher energy environments, primarily in the intertidal and shallow-water bank areas, are characterized by sand and gravel. Lower energy environments, primarily in lower side slope areas, are characterized by silts (Figure 3-3).

3.2.2 Geologic Units

Several distinct geologic units were identified based on subsurface sediment core profiles, diver observations, grain size data, and bathymetry. These geologic units are described below and portrayed in the geologic cross section on Figure 3-3.

Side Slope Silt (Unit 1). A soft, green to black, clayey, sandy SILT with shell fragments, wood fragments, and occasional layers of organic debris (i.e., leaves). This unit was encountered throughout the upper 3 feet of the side slope sediments along the Hylebos Waterway side of the site. This unit is probably characteristic of the side slope area on the Commencement Bay side as well, but sampling on the Commencement Bay side was limited to the bank.

Lower Bank Sand (Unit 2). A surface layer consisting of black, silty, gravelly SAND with shell fragments, wood, and metallic debris and occasional sandblast grit. This unit was encountered in the surficial sediments at the base of the riprap bank on the Commencement Bay and Hylebos Waterway side of the Industrial Yard, typically between elevations from -3 to 0 feet MLLW.

Upper Bank Gravel (Unit 3). A rust brown, sandy GRAVEL. A majority of these deposits were observed to contain metallic debris. This unit is typical of the discontinuous sediment deposits within the riprap on the upper portion of the embankment, above 0 feet MLLW.

Debris Piles. In addition to sedimentary units, exposed debris piles are encountered on the bank areas of the Hylebos Waterway side of the site near elevation 0 feet MLLW and below Pier 24 on the Commencement Bay side of the site (see Figures 3-2 and 3-3). Two primary debris piles were identified; one in front of the former AK-WA building, and the other about 200 feet north of the property boundary with Pioneer Chlor Alkali Company (as shown on Figures 3-2 and 3-3). The debris consists mainly of cobbles and fused, rusty pieces of scrap metal.

3.3 Sediment Grain Size Distribution

Selected sediment samples were submitted for grain size analysis at the Hart Crowser Geotechnical Laboratory. The laboratory grain size data were used to confirm field descriptions of surface and subsurface sediments, as presented in Appendix A. Grain size testing results for the selected samples are presented in Appendix C, including tabular summaries and cumulative curves. Based on the testing results, sediment samples were classified in accordance with the Unified Soil Classification (USC) System (ASTM D 2487, Figure C-1). A brief summary of these data is presented below.

3.3.1 Bank Sediment

Grain size testing was conducted on bank surface samples IY-B-2, IY-B-6, IY-B-8, and IY-B-10. The classification of these bank area sediment samples ranged from very gravelly SAND to slightly gravelly, silty SAND. The average grain size of the bank area was 16% gravel, 73% sand, 8% silt, and 3% clay.

3.3.2 Side Slope Sediment

Grain size testing was conducted on side slope core samples IY-C-1, and IY-C-5, at elevation -10 feet MLLW, and IY-C-2 and IY-C-6, at elevation -20 feet MLLW. The classification of these side slope area sediment samples ranged from clayey, very silty SAND to clayey, sandy SILT. The average grain size of the side slope area was 2% gravel, 32% sand, 47% silt, and 19% clay.

3.4 Sediment Total Organic Carbon

Total organic carbon (TOC) data for selected sediment samples are presented in Appendix B. This conventional parameter was generally analyzed in samples that were also submitted for analysis of organic chemical constituents (see Section 4). A summary of TOC data is presented below.

3.4.1 Upper Bank Sediment

The TOC content in the upper bank area sediment samples ranged from 1.6 to 5.5 percent. The lowest TOC content was measured in sample IY-UB-6; the highest TOC content was measured in sample IY-UB-10. The average upper bank sediment TOC is 3.3 percent. In spite of the gravelly texture of these sediments, TOC content was unusually high, suggesting possible contamination with petroleum products, such as waste oil.

3.4.2 Bank Sediment

The TOC content in bank area sediment samples ranges from 0.78 to 2.7 percent. The lowest TOC content was measured in sample IY-B-11; the highest TOC content was measured in sample IY-B-3. The average bank sediment TOC is 1.9 percent.

3.4.3 Side Slope Sediment

The TOC content in side slope sediment samples ranged from 1.9 to 2.4 percent. The lowest TOC content was measured in sample IY-S-6; the highest TOC content was measured in sample IY-S-4. The average TOC concentration in the Industrial Yard side slope samples is 2.1 percent.

3.4.4 Subsurface Sediment

The TOC content in the subsurface side slope sediment samples ranged from 2.1 to 4.1 percent. The lowest TOC content was measured in sample IY-C-06-S1 the highest TOC content was measured in sample IY-C-01-S2. The average TOC concentration in the Industrial Yard subsurface side slope samples is 2.9 percent.

3.5 Sediment Total Solids Content

Total solids content was determined for all sediment samples. Total solids content data are presented in Table B-1b and B-2b of Appendix B.

3.5.1 Upper Bank Sediment

The total solids content of the upper bank area sediment samples ranged from 74.9 to 85 percent. The lowest total solids content on the bank area was measured in sample IY-UB-5, whereas the highest total solids content was measured on sample IY-UB-6. The average total solids content of the upper bank area sediment samples is 79.3 percent.

3.5.2 Bank Sediment

The total solids content of the bank area sediment samples ranged from 50.1 to 74.3 percent. The lowest total solids content on the bank area was measured in sample IY-B-8, whereas the highest total solids content was measured on sample IY-B-2. The average total solids content of the bank area sediment samples is 62.9 percent.

3.5.3 Side Slope Sediment

The total solids content of the side slope sediment samples ranged from 44.3 to 47.5 percent. The lowest total solids content was measured in sample IY-S-8; the highest total solids content was measured in sample IY-S-2. The average total solids content of the side slope sediment samples is 46.6 percent.

3.5.4 Subsurface Sediment

The total solids content of the side slope sediment samples ranged from 45.9 to 57.2 percent. The lowest total solids content was measured in sample IY-C-1-S1; the highest total solids content was measured in sample IY-C-1-S2. The average total solids content of the subsurface sediment samples is 49.6 percent.

Diver Survey Map
Port of Tacoma Industrial Yard

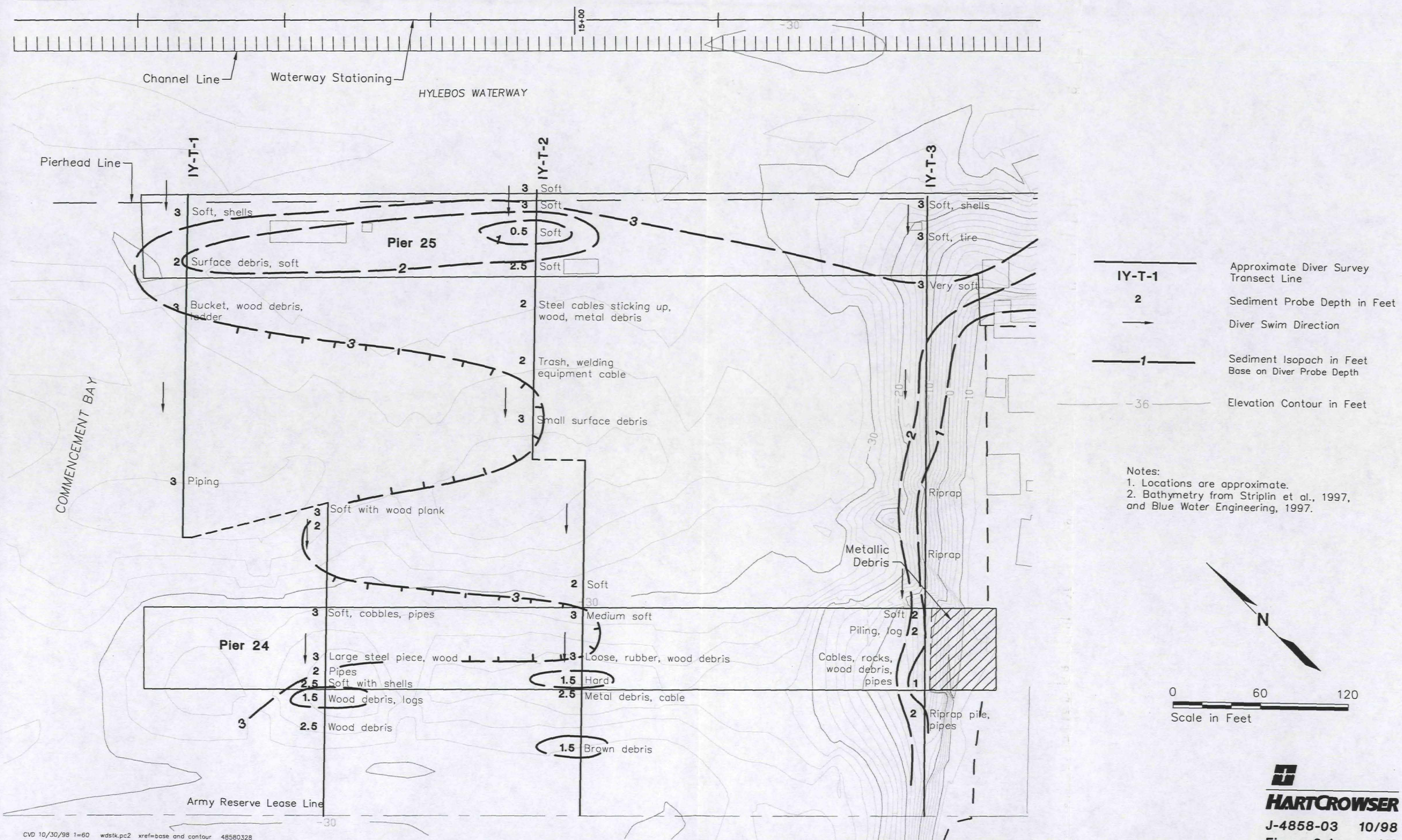


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Figure 3-1 1/3

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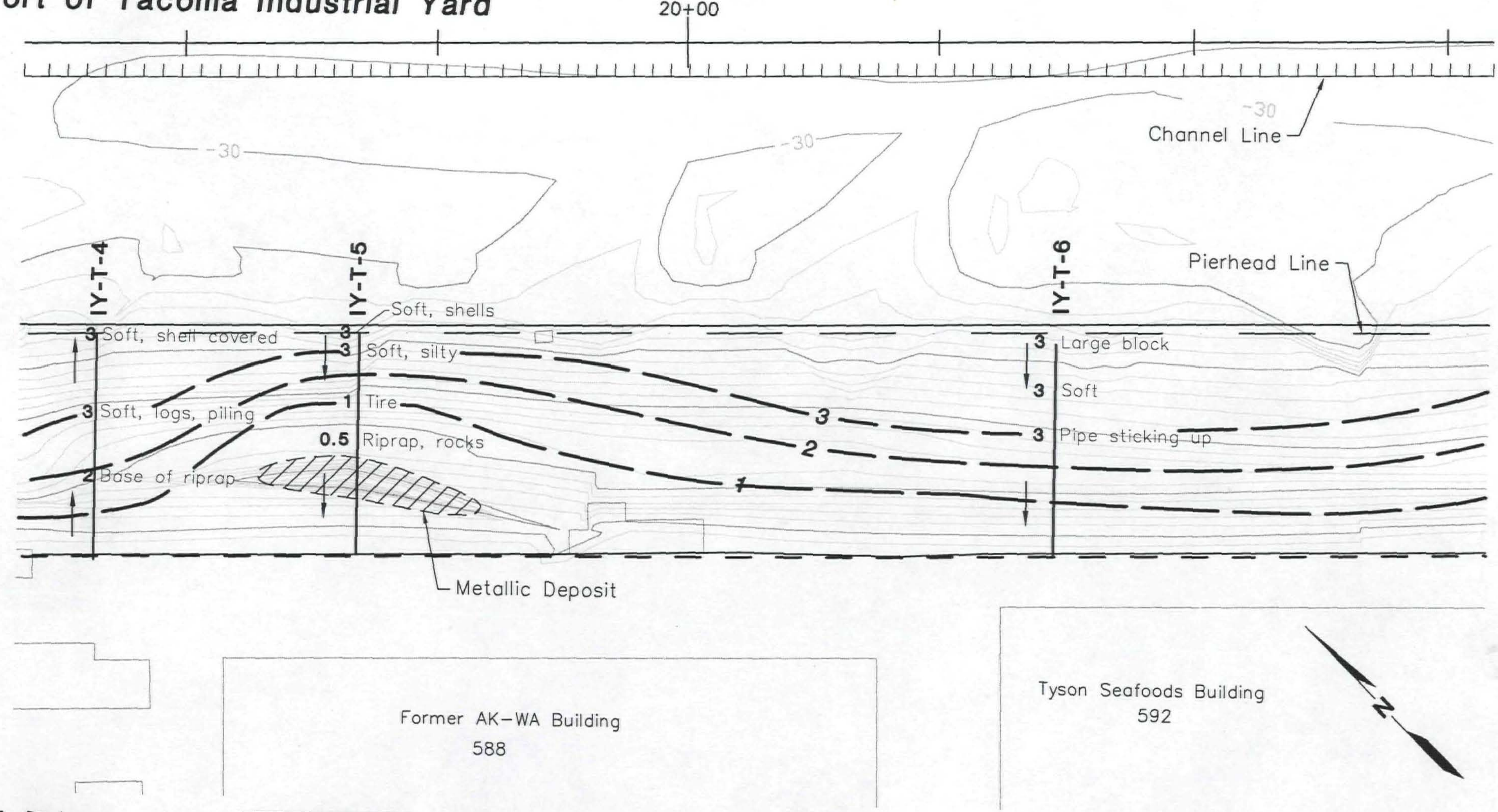
Diver Survey Map
Port of Tacoma Industrial Yard



IY-T-1 — Approximate Diver Survey Transect Line

2 — Sediment Probe Depth in Feet

→ — Diver Swim Direction

—1— — Sediment Isopach in Feet
Based on Diver Probe Depth

-36 — Elevation Contour in Feet

0 60 120
Scale in Feet

Notes:
1. Locations are approximate.
2. Bathymetry from Striplin et al., 1997, and Blue Water Engineering, 1997.

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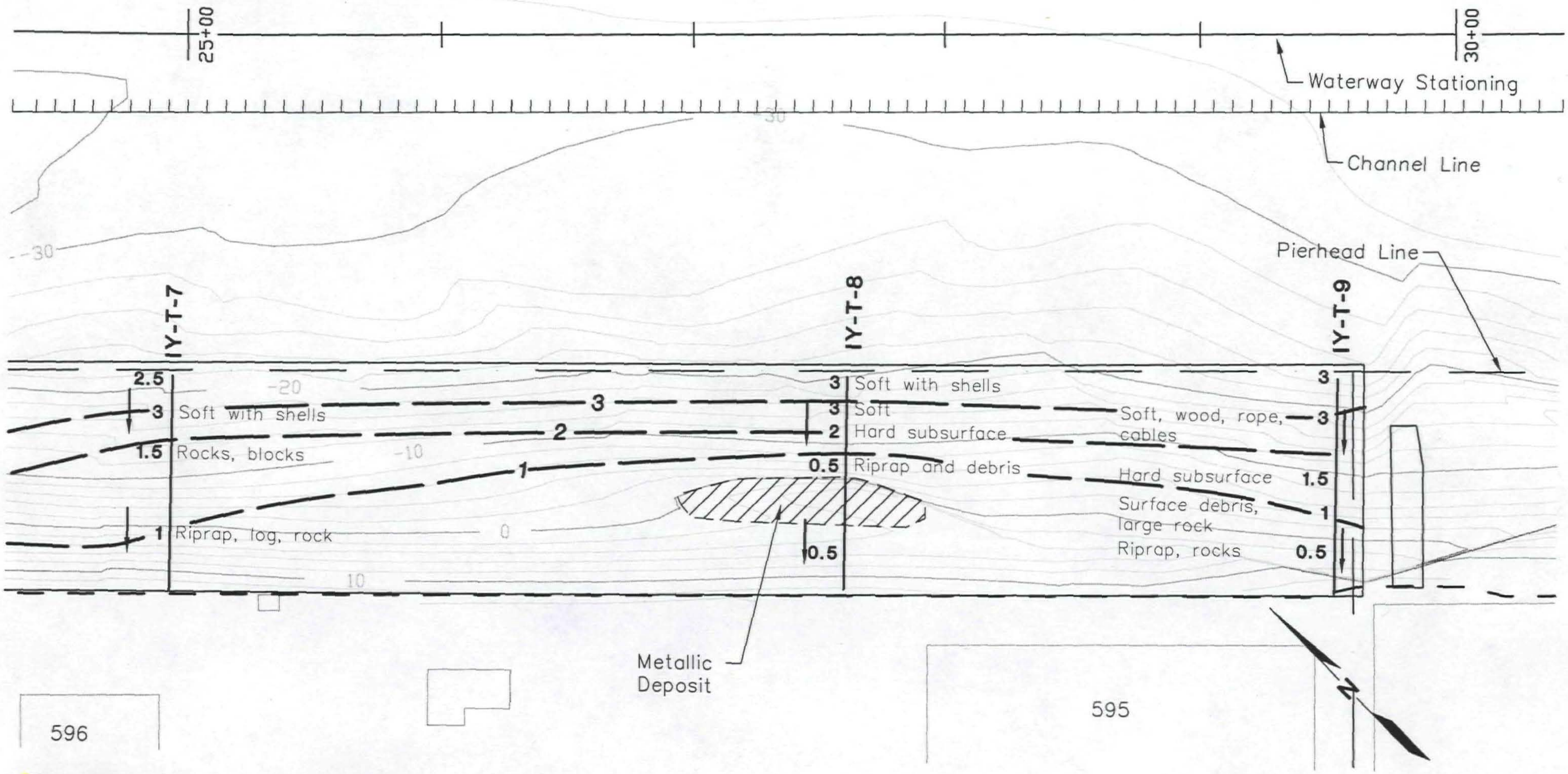
Figure 3-1 2/3

CVD 10/27/98 1=60 wdstk.pc2 48580330

Diver Survey Map
Port of Tacoma Industrial Yard



IY-T-1	Approximate Diver Survey Transect Line
2.5	Sediment Probe Depth in Feet
→	Diver Swim Direction
—1—	Sediment Isopach in Feet Based on Diver Probe Depth
-36	Elevation Contour in Feet

0 60 120

Scale in Feet

Notes:
1. Locations are approximate.
2. Bathymetry from Striplin et al., 1997, and Blue Water Engineering, 1997.

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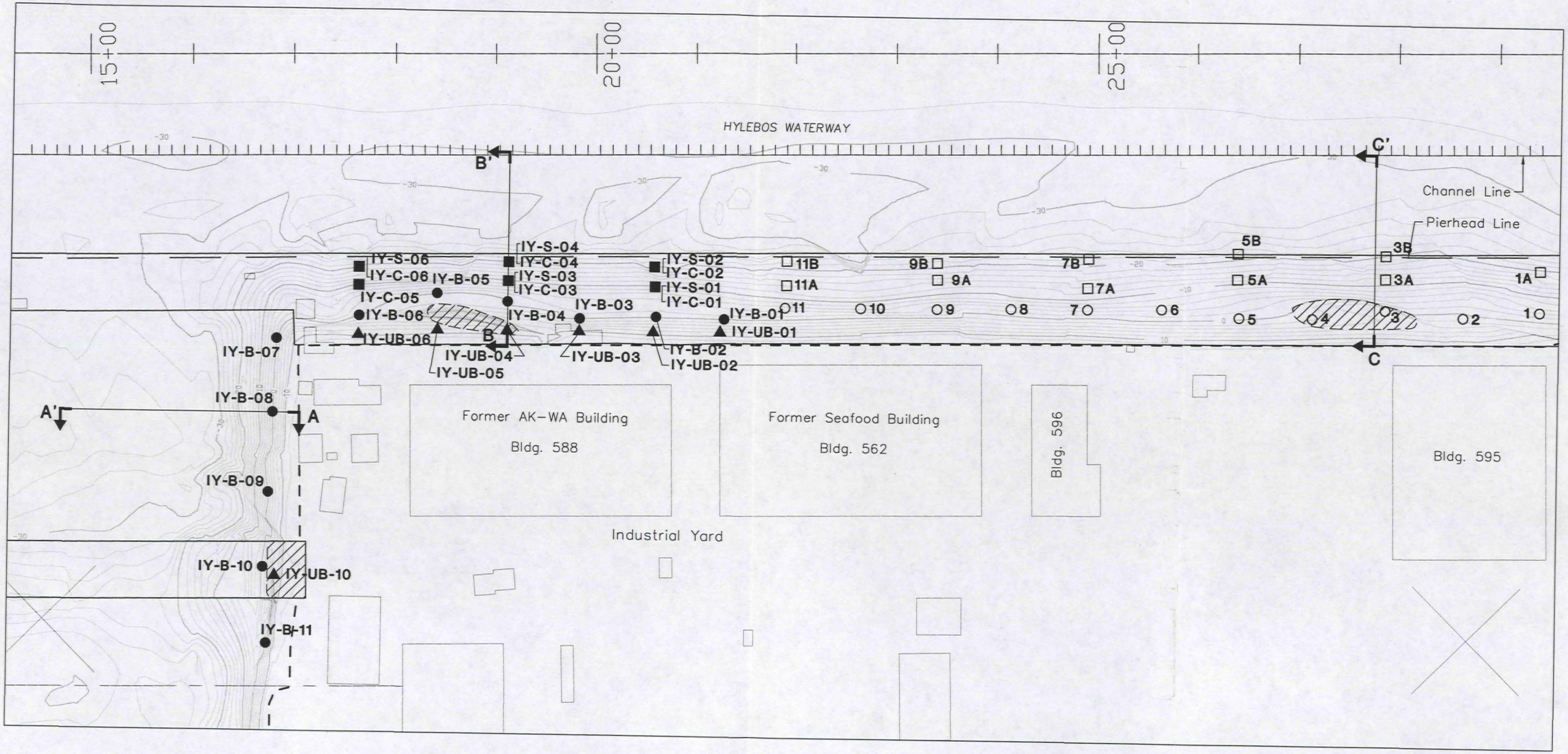
Figure 3-1 3/3

Cross Section Location Plan
Port of Tacoma Industrial Yard



Sample Location, Number, and Type

- ● IY-B-01 Bank Sample
- ▲ IY-UB-01 Upper Bank Sample
- ■ IY-S-01 Side Slope Surface Sample / IY-C-01 Collocated Subsurface Sample

Occidental Chemical Corporation, 1998
Sample Location, Number, and Type

- O 1 Bank Sample
- □ 1A Side Slope Surface Sample / Collocated Subsurface Sample

AA' Cross Section Location and Designation

Metallic Debris Piles

N

0 100 200
Scale in Feet

CVD 10/30/98 1=100 wdstk.pc2
48580325

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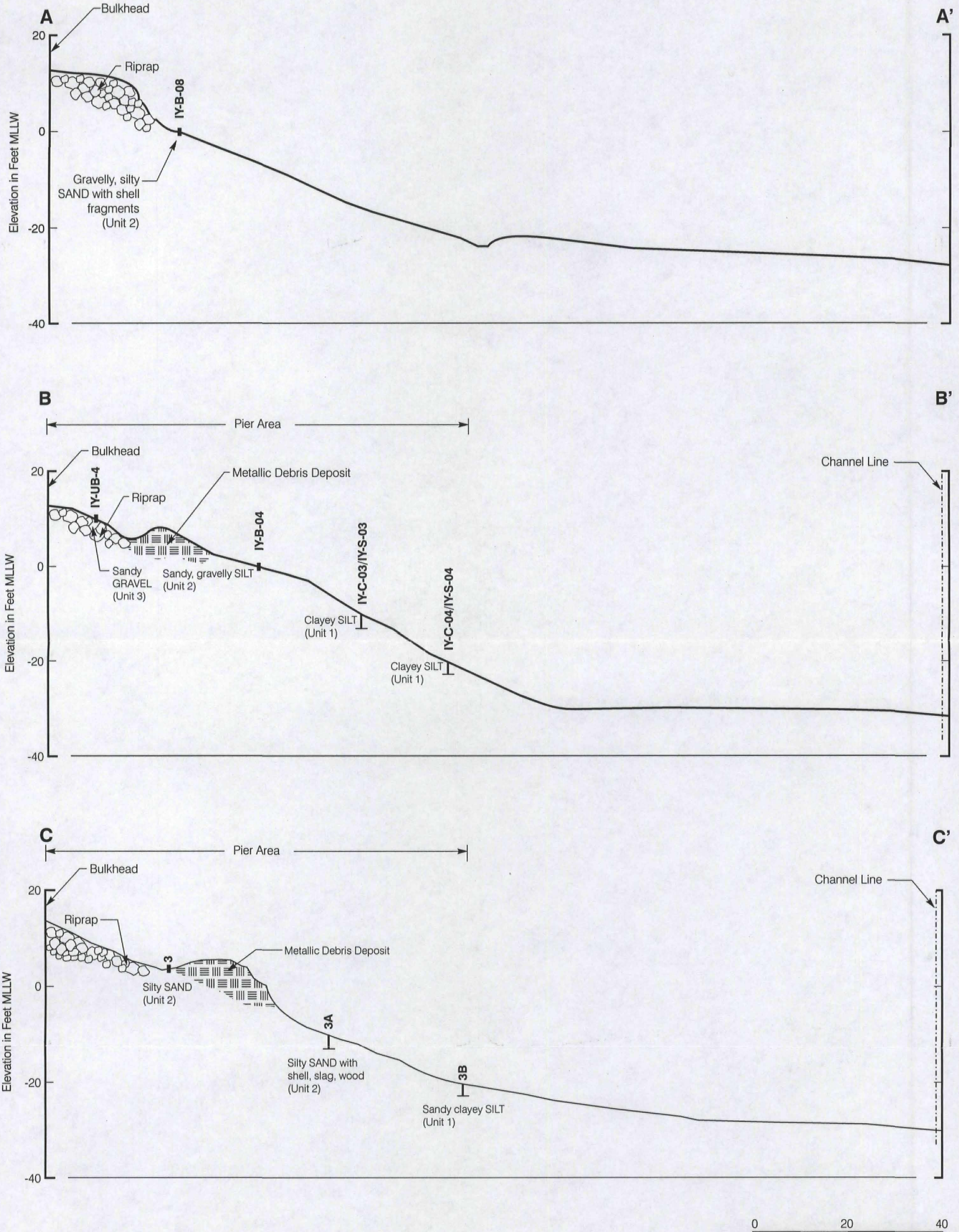
J-4858-03 10/98
Figure 3-2

Generalized Subsurface Cross Sections A-A', B-B', and C-C'
Port of Tacoma Industrial Yard



IY-C-01 Sediment Core Number and Location

IY-UB-02 Surface Sample Number and Location

Notes: 1. Depth of riprap is unknown.
2. Depth of metallic debris deposit unknown

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J-4858-03 8/98
Figure 3-3

Corel\485803\SECTIONS ABC

4.0 SEDIMENT CHEMICAL ANALYSIS

This section presents the results of chemical analyses of sediment samples collected in a joint investigation by the Port of Tacoma and Occidental Chemical Corporation (Oxychem) during the Pre-Remedial Design Study of Industrial Yard. The Port investigation provides sample coverage of the bay side of the Industrial Yard and the northern part of Pier 25 on the waterway side. The Oxychem investigation provides sample coverage of the southern part of Pier 25, south of Station 21+50.

The Port analytical data were subjected to an independent data quality review to ensure that project quality control/quality assurance requirements were met, as specified in the Project Plans (Port of Tacoma, 1997 and Hart Crowser, 1997a); the data quality review is summarized below and presented in detail in Appendix B. Laboratory certificates of analysis are provided in Appendix D. Raw data are on file at the Port of Tacoma. The Oxychem data are presented in Appendix E along with a data quality review of the Oxychem results.

Chemical analysis of sediment samples from the bank and side slope areas of the Industrial Yard was conducted primarily to determine the nature and extent of sediments that exceed SQOs and which, therefore, will require an evaluation of remedial options.

4.1 Data Quality Review

This section summarizes the data quality review conducted on the chemical analytical data obtained from both the Port study and the Oxychem study.

4.1.1 Port of Tacoma Data Quality

The Port data were collected in accordance with the Quality Assurance Project Plan (QAPP) for the Industrial Yard (Port, 1987). Sediment sampling was performed from January 19 through 22, 1998. Metals and organics/conventionals analyses were performed by Columbia Analytical Services and Analytical Resources Incorporated, respectively, consistent with the contract laboratories used by the Hylebos Waterway Cleanup Committee (HCC) in the pre-remedial design study of the Hylebos Waterway.

Columbia Analytical Services and Analytical Resources Inc. submitted CLP-equivalent data packages; these packages were independently validated by Hart Crowser, Inc., in accordance with the QAPP, specific method requirements, and EPA Data Validation Functional Guidelines (EPA, 1994a and 1994b). Data qualifiers are consistent with the Functional Guidelines. The detailed data validation summary, including the evaluation of project-specific data quality objectives and the analytical quality control objectives, is presented in Appendix B.

Based on the data validation results, the overall data quality objectives were met for sampling and analysis at the Industrial Yard site. The completeness for the associated data is 100 percent. Therefore, the data presented herein are of suitable quality for use in pre-remedial design. A discussion of the project data quality is presented below by sample types.

Side Slope Sediment Data Quality. Nineteen side slope sediment samples, including surface (0 to 10 cm) and subsurface (0 to 3+ feet) samples, plus field QA/QC samples, were collected and analyzed. The side slope sediments extend from elevation 0 feet MLLW to the Pierhead Line, at approximately -20 to -30 feet MLLW. A summary of analytical results for surface and subsurface side slope sediment samples are listed in Tables B-1 and B-2, respectively.

Detection limits exceeded SQOs for some semivolatile compounds due to matrix interference and/or elevated concentrations of target compounds. Detection limits for 2-methylphenol, 2,4-dimethylphenol, 1,2-dichlorobenzene, 1,2,4-trichlorobenzene, and n-nitrosodiphenylamine exceeded their respective SQOs in several samples; however, the elevated detection limits were generally within 2 times the SQO, and these chemicals were not detected in any other samples from the site (except 1,2,4-trichlorobenzene which was detected below the SQO in 1 of 35 samples), so it is unlikely that they contribute significantly to site risk. Higher detection limit exceedences for some phenols, chlorobenzenes, and other semivolatile compounds were reported for sample IY-S-03, because this sample contained matrix interference resulting from elevated concentrations of PAHs.

Bank Sediment Data Quality. Twenty surface (0 to 10 cm) sediment samples, including field QA/QC samples, were collected and analyzed from the bank and upper bank areas. Bank sediment samples were collected near 0 feet MLLW at the base of riprap; upper bank samples were collected near 6 feet MLLW from gravelly pockets within the riprap. A summary of analytical results for bank and upper bank surface sediment samples are listed in Tables B-3 and B-4, respectively.

Detection limits exceeded SQOs for some semivolatile compounds and pesticides due to matrix interference and/or elevated concentrations of target compounds. Detection limits for 2-methylphenol, 2,4-dimethylphenol, 1,2-dichlorobenzene, 1,2,4-trichlorobenzene, and n-nitrosodiphenylamine exceeded their respective SQOs in several samples; however, the elevated detection limits were generally within 2 times the SQO, and these chemicals were not detected in any other samples from the site (except 1,2,4-trichlorobenzene which was detected below the SQO in 1 of 35 samples), so it is unlikely that they contribute significantly to site risk. Higher detection limit exceedences for some DDT isomers, chlorobenzenes, and hexachlorobutadiene were reported for samples IY-B-01, IY-B-02, IY-B-05, IY-UB-01, and IY-UB-02, because these samples contained matrix interference resulting from elevated concentrations of PCBs.

4.1.2 Oxychem Data Quality

The Oxychem data were collected between January 9 and 21, 1998. Analysis was conducted by Analytical Resources Incorporated. The chemical data were reviewed for quality assurance/quality control; data validation reports are presented in Appendix E.

Based on the data validation results, the overall data quality objectives were met. The completeness for the associated data is 99.9 percent. Several antimony results were rejected due to low matrix spike recoveries. Remaining data are suitable for use in pre-remedial design.

Thirteen bank samples and 33 side slope samples were collected and analyzed. Detection limits exceeded SQOs for several semivolatile compounds due to matrix interference and/or elevated concentrations of target compounds. Detection limits for 1,2-dichlorobenzene and n-nitrosodiphenylamine exceeded their respective SQOs in several samples; however, these chemicals were not detected in any samples from the site with adequate detection limits. Detection limits for 1,3-dichlorobenzene, 1,4-dichlorobenzene, 1,2,4-trichlorobenzene, 2,4-dimethylphenol, pentachlorophenol, 4-methylphenol, and dimethylphthalate exceeded their respective SQOs in several samples; these compounds were also detected in site samples, but at concentrations below the SQO.

Hexachlorobutadiene, hexachlorobenzene, 4,4'-DDT and its breakdown isomers, and 2-methylphene had detection limits greater than the SQOs. These compounds were also detected in site samples at concentrations greater than their respective SQOs. Therefore, sample locations with undetected concentrations may contain these contaminants at concentrations of concern based on their occurrence at other locations.

4.2 Sediment Chemical Analytical Results

This section presents the chemistry results and summary statistics for the bank, upper bank, and side slope, surface and subsurface sediment samples collected during the Port study and the Oxychem study. Tables 4-1, 4-2, 4-3, and 4-4 present the statistical summaries of sediment quality data for the bank, upper bank, surface side slope, and subsurface side slope areas, respectively. These tables include detection frequencies, concentration ranges, maximum concentrations and the locations of these maxima, and exceedence statistics (as discussed below) for each analyzed constituent. Duplicate samples were not included in the summary statistics so that the chemistry from those locations would not be doubly represented. Supporting data tables are presented in Appendix B and Appendix E.

Sediment quality is evaluated by comparing the sediment chemical data with the SQOs established in the Commencement Bay ROD (EPA, 1989). However, the SQO for PCBs was recently revised by EPA to 300 µg/kg for protection of human health from consumption of seafood with bioaccumulated PCBs. SQO comparisons are quantified and prioritized through the use of exceedence statistics. Exceedence statistics include frequency of exceedence (number of SQO exceedences per number of samples analyzed) and maximum enrichment ratio (ER, maximum detected concentration divided by the SQO).

4.2.1 Comparison of Bank Sediment Concentrations to SQOs

Bank samples were collected near 0 feet MLLW, near the highest elevation of continuous sediment coverage, and where subtidal sediments lap against the base of the riprapped bank.

As indicated in Table 4-1, zinc, arsenic, copper, lead, and mercury were detected in the 22 Port and Oxychem bank samples. Zinc concentrations exceeded the SQO of 410 mg/kg in 19 samples (nine Port samples, ten Oxychem samples). Sample IY-B-02 had the highest concentration with an ER = 12.6. Arsenic exceeded its SQO of 57 mg/kg in six samples (two Port samples, four Oxychem samples). The highest concentration occurred in sample IY-B-09 (ER = 2.0). The SQO for copper of 390 mg/kg was exceeded in twelve samples (six Port samples, six Oxychem samples). The maximum ER occurred in sample 9 (ER = 39.5). Lead concentrations exceeded the SQO in four samples; the maximum ER of 7.4 was detected in sample 3. For mercury, four samples (one Port sample, three Oxychem samples) exceeded the SQO of 0.59 mg/kg with a maximum ER of 2.34 in sample 9.

In addition, nickel and silver were detected in the Oxychem samples. The SQOs for these metals were slightly exceeded in one sample for each metal with maximum ERs of 1.0 and 1.1, respectively. Antimony and cadmium were detected in the Oxychem samples; however, concentrations did not exceed the SQOs for these metals.

Total PCBs concentrations exceeded the SQO of 300 µg/kg in 13 samples (five Port samples and eight Oxychem samples). The highest concentration occurred in sample IY-B-01 with an ER = 27.0. One sample result (IY-B-01) exceeded the SQO for 4,4'-DDT of 34 µg/kg with an ER = 4.4. One Oxychem sample result (9) exceeded the SQO for 4,4'-DDD with an ER of 5.5.

Pentachlorophenol was detected in one bank sample (IY-B-02). The SQO of 360 µg/kg was exceeded in this sample with an enrichment ratio of 1.4.

Several PAHs were detected in the bank samples. Of the LPAHs, acenaphthene, anthracene, and phenanthrene were detected in the bank samples at concentrations above the SQOs. Acenaphthene and fluorene was detected in three Oxychem samples; the maximum ERs of 2.2 and 2.0 were both from sample 10. Concentrations of anthracene exceeded the SQO of 960 µg/kg in six samples (two Port samples and four Oxychem samples); the highest concentration occurred in sample 10 with an ER = 6.0. Twelve samples (eight Port samples and four Oxychem samples) exceeded the SQO of 1,500 µg/kg for phenanthrene. The highest concentration occurred in sample 10 (ER = 10.0).

Several HPAHs were detected at concentrations exceeding their respective SQOs. Sample IY-B-03 contained the highest concentrations of HPAH compounds. Fluoranthene concentrations exceeded the SQO of 2,500 µg/kg in sixteen samples (ten Port samples, five Oxychem samples); the maximum ER was 6.5. Fourteen samples (nine Port samples, five Oxychem samples) exceeded the SQO for dibenz(a,h)anthracene of 230 µg/kg with a maximum ER of 8.7. The SQO for benzo(a)anthracene of 1,600 µg/kg was exceeded in twelve samples (seven Port samples, five Oxychem samples). The maximum ER was 6.3. Pyrene concentrations exceeded the SQO of 3,300 µg/kg in eleven samples (six Port samples, five Oxychem samples); the maximum ER was 5.8. Benzo(a)pyrene and indeno(1,2,3-cd)pyrene concentrations exceeded their respective SQOs in 10 and 9 samples, respectively. Maximum ERs = 5.5 and 6.5. The SQO for chrysene of 2,800 µg/kg was exceeded in eight samples (four Port samples, four Oxychem samples). The maximum ER was 5.0. The SQO for benzo(g,h,i)perylene of 720 µg/kg was exceeded in six samples (two Port samples, four Oxychem samples) with a maximum ER of 5.0.

Four semivolatiles were detected in the bank sediment samples. Hexachlorobenzene exceeded the SQO of 22 µg/kg in seven samples (one Port sample, six Oxychem samples) with a maximum ER = 5.0. Two samples exceeded the SQO for dimethylphthalate of 160 µg/kg with a maximum ER = 2.8 at IY-B-01. Bis(2-ethylhexyl)phthalate also exceeded the SQO of 1,300 µg/kg in two samples (IY-B-04 and 10) with a maximum ER = 1.8. The SQO for benzyl alcohol, butylbenzophthalate, and hexachlorobenzene was exceeded in one sample each; maximum ERs = 2.3, 2.8, and 1.6, respectively.

4.2.2 Comparison of Upper Bank Sediment Concentrations to SQOs

Upper bank samples were collected near elevation 6 feet MLLW, in discontinuous patches of coarse, gravelly sediment in the interstices of the riprap.

As indicated in Table 4-2, zinc, arsenic, copper, lead, and mercury were detected in seven upper bank samples (IY-UB-01 through IY-UB-06 and IY-UB-10). The upper bank areas were not sampled in the Oxychem study. Zinc concentrations exceeded the SQO of 410 mg/kg in the seven samples. The highest concentration occurred in sample IY-UB-05 (ER = 8.5). The SQO for arsenic of 57 mg/kg was exceeded in two samples (IY-UB-05 and IY-UB-10). The highest concentration occurred in sample IY-UB-05 (ER = 1.2). Copper concentrations exceeded the SQO of 390 mg/kg in four samples (IY-UB-02, IY-UB-05, IY-UB-06, and IY-UB-10). The highest concentration occurred in sample IY-UB-06 (ER = 3.5). Two samples (IY-UB-01 and IY-UB-10) exceeded the SQO for lead of 450 mg/kg; sample IY-UB-01 had the maximum ER = 1.8. Mercury concentrations exceeded the SQO of 0.59 mg/kg in two samples (IY-UB-01 and IY-UB-10). Sample IY-UB-01 had the highest concentration with an ER = 1.9.

Total PCBs were detected in the seven upper bank samples. The SQO of 300 µg/kg was exceeded in two samples (IY-UB-01 and IY-UB-02); the highest concentration occurred in sample IY-UB-01 with an ER of 107. 4,4′-DDT concentrations exceeded the SQO of 34 µg/kg in one sample (IY-UB-04) with an ER = 1.1.

Several PAHs were detected in the seven upper bank samples. Of the LPAHs, phenanthrene and anthracene exceeded their respective SQOs and had the highest concentrations in samples IY-UB-02. The SQO for phenanthrene of 1,500 µg/kg was exceeded in three samples (IY-UB-01, IY-UB-02, and IY-UB-03) with a maximum ER = 2.5. One sample marginally exceeded the SQO for anthracene of 960 µg/kg (ER = 1.0).

Of the HPAHs, fluoranthene concentrations exceeded the SQO of 2,500 µg/kg in two samples (IY-UB-01 and IY-UB-02). The highest concentration occurred in sample IY-UB-01 with an ER of 1.7. Pyrene, benzo(a)anthracene, and benzo(g,h,i)perylene concentrations exceeded their respective SQOs in one sample (IY-UB-02) with ER of 1.2, 1.3, and 1.0, respectively. One sample (IY-UB-01) marginally exceeded the SQO for indeno(1,2,3-cd)pyrene of 690 µg/kg

(ER = 1.0), and another sample (IY-UB-04) marginally exceeded the SQO for dibenz(a,h)anthracene of 230 µg/kg (ER = 1.0).

Two semivolatiles were detected in the upper bank samples. The SQO for hexachlorobutadiene of 11 µg/kg was exceeded in one sample (IY-UB-10, ER = 3.5). The SQO for dimethylphthalate of 160 µg/kg was also exceeded in one sample (IY-UB-02, ER = 7.5).

4.2.3 Comparison of Surface Side Slope Sediment Concentrations to SQOs

As presented in Table 4-3, cadmium, copper, and zinc were detected above SQOs in surface sediment samples from the side slope area. Cadmium was present at a concentration exceeding the SQO of 5.1 mg/kg in one sample, IY-S-02 (ER = 1.7). Copper exceeded its SQO of 390 mg/kg in only one sample, IY-S-01 (ER = 1.3). The SQO for zinc of 410 mg/kg was exceeded in four samples (two Port samples, two Oxychem samples); the highest concentration occurred in sample IY-S-02 (ER = 12.5).

Concentrations of total PCBs exceeded the SQO in six Oxychem samples. The maximum ER = 11.5 in sample 9A. 4-4'-DDD concentrations exceeded the SQO in two Oxychem samples with maximum ER = 1.4 in sample 9A. 4-4'-DDT was present in sample 3B at a concentration slightly above the SQO (ER = 1.0).

Several PAHs were detected in the surface samples from the side slope. Of the low molecular weight PAHs (LPAHs), concentrations of 2-methylnaphthalene, acenaphthene, anthracene, fluorene, naphthalene, and phenanthrene exceeded the SQOs. 2-Methylnaphthalene and naphthalene were detected at concentrations exceeding their respective SQOs only in sample 9B (ERs = 13.0 and 5.2, respectively). Concentrations of acenaphthene exceeded the SQO in three Oxychem samples (maximum ER = 19.8). Fluorene exceeded its SQO of 540 µg/kg in five samples (one Port sample, four Oxychem samples). Eleven samples (three Port samples, eight Oxychem samples) exceeded the SQO for phenanthrene of 1,500 µg/kg; the highest concentration occurred in sample 9B with an ER = 32.0. Concentrations of anthracene exceeded the SQO of 960 µg/kg in twelve samples (three Port samples, nine Oxychem samples). The highest concentration occurred in sample 5B with an enrichment ratio of 9.0.

Several high molecular weight PAHs (HPAHs) were detected at concentrations exceeding their respective SQOs. Concentrations of fluoranthene and indeno(1,2,3-cd)pyrene exceeded their respective SQOs in fifteen samples; the maximum ERs = 12.4 and 3.6, respectively. Pyrene, benzo(a)anthracene, chrysene, benzo(a)pyrene, and dibenz(a,h)anthracene were present at concentrations exceeding their respective SQOs in fourteen samples (four Port samples, ten Oxychem samples); the highest concentrations occurred in sample 9B with ERs of 7.8, 5.4, 3.6, 4.2, and 7.0, respectively. Benzo (g,h,i)perylene concentrations exceeded the SQO of 720 µg/kg in seven samples (three Port samples, four Oxychem samples). The maximum ER (2.5) occurred in sample 9B.

Of the remaining semivolatiles, bis(2-ethylhexyl)phthalate 1,2,4-trichlorobenzene, dibenzofuran, hexachlorobenzene, and hexachlorobutadiene were detected in the surface side slope sediments at concentrations greater than the SQO with maximum ERs of 2.8, 1.0, 11.1, 17.3, and 191, respectively.

One volatile organic compound, tetrachloroethene, was detected in sample 1A at a concentration 2.5 times greater than the SQO of 57 µg/kg.

4.2.4 Comparison of Subsurface Side Slope Sediment Concentrations to SQOs

As indicated in Table 4-4, arsenic, cadmium, zinc, copper, lead, mercury, and nickel were detected in subsurface samples analyzed from the side slope area at concentrations greater than their respective SQOs. Arsenic was detected at concentrations above its SQO in seven Oxychem samples. Cadmium concentrations exceeded its SQO in six Oxychem samples. Nickel was detected above its SQO in one sample (9A). Maximum ERs = 3.5, 1.5, and 1.5, respectively, for arsenic, cadmium, and nickel. The SQO for zinc of 410 mg/kg was exceeded in thirteen samples (four Port samples, nine Oxychem samples). The highest concentration occurred in sample 9A with an ER = 5.7. Copper concentrations exceeded the SQO of 390 mg/kg in six samples (three Port samples, three Oxychem samples). The highest concentration occurred in sample 3A (ER = 4.9). The SQO for lead of 450 mg/kg was exceeded in nine samples (two Port samples, seven Oxychem samples). The highest concentration occurred in sample 9A (ER = 4.3). Fourteen samples (three Port samples, eleven Oxychem samples) exceeded the SQO for mercury of 0.59 mg/kg. The maximum ER (5.1) occurred in sample IY-C-01-S2.

Total PCBs were detected in 33 subsurface samples from the side slope area. The SQO of 300 µg/kg was exceeded in 24 samples (four Port samples, 20 Oxychem samples); the highest concentration occurred in sample 7A with an ER = 28.2. The SQO for 4,4'-DDE of 9 µg/kg was exceeded in one sample (IY-C-05-S2, ER = 2.3). 4,4'-DDD concentrations exceeded the SQO of 16 µg/kg in twelve samples (four Port samples, eight Oxychem samples). The highest concentration occurred in sample 9A with an ER = 5.8. The SQO for 4,4'-DDT of 34 µg/kg was exceeded in one sample (IY-C-01-S2) with an ER = 1.9.

Several PAHs were detected in subsurface samples from the side slope area. The LPAHs which exceeded their respective SQOs were 2-methylnaphthalene, acenaphthene, fluorene, naphthalene, phenanthrene, and anthracene. The highest concentration in each case occurred in sample 1A with the exception of acenaphthene where the highest concentration was detected in sample 7A. The SQO for 2-methylnaphthalene of 670 µg/kg was exceeded in seven samples (three Port samples, four Oxychem samples) with a maximum ER = 5.2. Acenaphthene, fluorene, and anthracene concentrations exceeded their respective SQOs in fifteen samples with maximum ER = 17.6, 9.6, and 5.5, respectively. The SQO for phenanthrene of 1,500 µg/kg was exceeded in sixteen samples (five Port samples, eleven Oxychem samples), with a maximum ER = 16.7. Naphthalene concentrations exceeded the SQO of 2,100 µg/kg in four Oxychem samples with a maximum ER = 20.5.

Of the HPAHs, the SQO for dibenz(a,h)anthracene of 230 µg/kg was exceeded in twenty-six samples. The highest concentration occurred in sample IY-C-03-S2 with an enrichment ratio of 7.8. Indeno(1,2,3-cd)pyrene concentrations exceeded the SQO of 690 µg/kg in twenty-two samples (ten Port samples and twelve Oxychem samples). The highest concentration occurred in sample IY-C-03-S2 (ER = 4.8). The SQO for pyrene of 3,300 µg/kg was exceeded in twenty-three samples (eight Port samples, fifteen Oxychem samples). The highest concentration occurred in sample IY-C-01-S2 with an ER = 7.0. Benzo(g,h,i)perylene concentrations exceeded the SQO of 720 µg/kg in fourteen samples (eight Port samples, six Oxychem samples). The maximum ER (4.7) occurred in sample IY-C-03-S2. Fluoranthene and benzo(a)pyrene concentrations exceeded their SQO in sixteen samples. The highest concentration occurred in samples 1A and IY-C-03-S2 with a maximum ERs = 7.2 and 4.7, respectively. Benzo(a)anthracene and chrysene concentrations exceeded their SQOs in 13 and 12 samples, respectively. Maximum ERs = 3.8 and 2.9, respectively, for these two HPAHs.

Three semivolatiles were detected in the subsurface samples from the side slope area. The SQO for hexachlorobenzene of 22 µg/kg was exceeded in seventeen samples (two Port samples, fifteen Oxychem samples). The highest concentration occurred in sample 1A with an ER = 255. Hexachlorobutadiene concentrations exceeded the SQO of 11 µg/kg in fifteen samples (four Port samples, eleven Oxychem samples). The maximum ER (6,545) occurred in sample 1A. The SQO for bis(2-ethylhexyl)phthalate of 1,300 µg/kg was exceeded in ten samples (three Port samples, seven Oxychem samples). The highest concentration occurred in sample IY-C-05-S2 (ER = 2.5).

1,2,4-Trichlorobenzene, dibenzofuran, and tetrachloroethene were detected in Oxychem samples only, at concentrations greater than the SQOs. Maximum ERs = 7.4, 7.2, and 632, respectively.

4.3 Ranking of Constituents of Concern

The constituents which exceeded the SQO criteria in surface and subsurface sediments were prioritized to a short list of constituents of concern that can be expected to drive future remedial design efforts, based on exceedence statistics. Constituents were ranked independently using the exceedence frequency (number of samples exceeding SQO per number of samples analyzed with detection limits at or below SQO, expressed as a percent) and maximum enrichment ratio (ratio of maximum sample concentration to SQO concentration). The ranking scores based on these two statistics were added to produce a combined ranking score, and the combined ranking score was sorted to produce the ordered list of constituents in Tables 4-5 and 4-6 for surface and subsurface sediments, respectively. Constituents with lowest combined ranking scores exhibit the highest rate of SQO exceedence and the most elevated concentrations relative to SQOs.

This type of ranking scheme provides a relatively simple means of prioritizing waterway pollutants, and selecting a list of key constituents to help focus remedial design efforts. However, other environmental factors may ultimately need to be considered in the selection of a cleanup action, such as the distinction between ecological and human health risk.

4.3.1 Constituents of Concern in Surface Sediment

Based on the SQO exceedence statistics of Table 4-5, the following chemicals are selected as constituents of concern in the surface sediments of the Industrial Yard Area, in order of priority:

- Phenanthrene;
- Total PCBs;
- Zinc;
- Fluoranthene;
- Copper;
- Hexachlorobutadiene; and
- Dibenz(a,h)anthracene.

These constituents represent the major groups of problem chemicals in surface sediments from the Industrial Yard. Zinc and copper are the target metals in surface sediments. Phenanthrene was selected as the surrogate for the LPAH group, and fluoranthene and dibenz(a,h)anthracene were selected as surrogates for the HPAH group, providing representation of the range of chemical characteristics and mobility for the PAH compounds. PCBs and hexachlorobutadiene represent chlorinated organic compounds. These compounds exhibit some of the most extreme enrichment ratios, peaking at 107 and 191 times the SQO, respectively.

4.3.2 Constituents of Concern in Subsurface Sediment

A similar ranking of constituents was performed using the data set of subsurface core samples, and is presented in Table 4-6. The following chemicals are selected as constituents of concern in the subsurface sediments of the Industrial Yard Area, in order of priority:

- Hexachlorobutadiene;
- Total PCBs;
- Dibenz(a,h)anthracene;
- Phenanthrene;
- Zinc; and
- Mercury.

These constituents represent the major groups of problem chemicals in subsurface sediments from the Industrial Yard. Mercury and zinc are the target metals. Phenanthrene is the highest ranked chemical for the LPAH group, and dibenz(a,h)anthracene is the highest ranked chemical for the HPAH group. The chlorinated compounds—PCBs and hexachlorobutadiene—also ranked highly because of extreme enrichment ratios peaking at 28 and 6,545 times the SQO, respectively.

Several other organic compounds exhibited frequent and/or high enrichments above their respective SQOs, but these compounds were generally eclipsed by higher enrichments of HCBD or PCBs at the same location. Several chlorinated, semivolatile and volatile compounds—2,4-dimethylphenol, hexachlorobenzene, ethylbenzene, tetrachloroethene, 1,2,4-trichlorobenzene, and xylenes—are correlated with generally higher enrichments of HCBD. Elevated concentrations of DDT isomers are correlated with PCBs and/or HCBD. An unusual signature of acenaphthene, dibenzofuran, and ethylbenzene is correlated with high PCB concentrations at location 7A.

4.3.3 Constituents of Concern for Pre-Remedial Design

Combining the ranking results for both surface and subsurface sediments, a master list of constituents of concern was developed for the Industrial Yard, including the following:

- Zinc;
- Copper;
- Mercury;
- Phenanthrene;
- Dibenz(a,h)anthracene;
- PCBs; and
- Hexachlorobutadiene.

Zinc, copper, and mercury were selected as the target metals; these metals comprise a typical suite of contaminants encountered near historical shipyard sites. Phenanthrene was selected as the overall surrogate for the LPAHs, because it was the highest ranked LPAH in surface and subsurface sediments. Dibenz(a,h)anthracene was selected as the overall surrogate for HPAHs, and this compound was the highest ranked HPAH in subsurface sediments and the second-highest ranked HPAH in surface sediments, behind fluoranthene. PCBs ranked highly in both surface and subsurface sediments. PAHs and PCBs are common environmental contaminants that may be derived from a variety of industrial and urban sources. Hexachlorobutadiene (HCBD) exhibited some of the most extreme enrichments in surface and subsurface sediments. This chemical is commonly encountered in the outer portion of the Hylebos Waterway and is a primary driver in the HCC remedial design.

This list of constituents of concern is intended to serve as indicator chemicals for the major groups of contaminants in Industrial Yard sediments. The distribution and magnitude of SQO exceedences for these constituents of concern encompass SQO exceedences of other lesser priority chemicals, and thus help to circumscribe and delineate remedial action areas. For example, exceedences of the target metals encompass lesser exceedences of lead and arsenic; exceedences of PCBs encompass lesser exceedences of DDT isomers; exceedences of the PAHs encompass lesser exceedences of other semivolatile compounds such as phthalates; and exceedences of HCBD encompass lesser exceedences of other chlorinated and semivolatile compounds such as hexachlorobenzene, 2,4-dimethylphenol, and ethylbenzene.

The spatial distribution of these constituents of concern is described in Section 5.

Table 4-1 - Statistical Summary of Analytical Results for Bank Samples

Analyte	Detection Frequency	Range	Maximum Detection	Sample ID of Max. Detect.	Exceedence Frequency	Enrichment Ratio	SQO
Conventionals in percent							
Total Organic Carbon	11/11	0.78 to 2.7	2.7	IY-B-03			
Total Solids	11/11	50.1 to 74.3	74.3	IY-B-02			
Metals in mg/kg							
Antimony	11/11	3.6 J to 53 J	53 J	9	0/11		150
Arsenic	22/22	16.8 J to 116	116	IY-B-09	6/22	2.0	57
Cadmium	11/22	0.12 J to 1.7 J	1.7 J	9	0/22		5.1
Chromium	11/11	30.4 to 219	219	3			
Copper	22/22	59.8 J to 15400	15400 J	9	12/22	39.5	390
Lead	22/22	59.4 J to 3320 J	3320 J	3	4/22	7.4	450
Mercury	22/22	0.06 J to 1.38	1.38	9	4/22	2.3	0.59
Nickel	11/11	23.4 to 144	144	9	1/11	1.0	140
Silver	11/11	0.04 to 6.9	6.9	12	1/11	1.1	6.1
Zinc	22/22	176 J to 5160 J	5160 J	IY-B-02	19/22	12.6	410
Pesticide/PCBs in µg/kg							
Aroclor 1016	0/22	18 U to 1300 U	N/A				
Aroclor 1221	0/22	36 U to 2600 U	N/A				
Aroclor 1232	0/22	18 U to 1300 U	N/A				
Aroclor 1242	0/22	18 U to 1300 U	N/A				
Aroclor 1248	0/22	18 U to 1300 U	N/A				
Aroclor 1254	4/22	18 U to 1900	1900	11			
Aroclor 1260	19/22	26 U to 8100	8100	IY-B-01			
Total PCBs	19/22	37 U to 8100	8100	IY-B-01	13/22	27.0	300
Aldrin	0/11	0.93 U to 65 U	N/A				
Dieldrin	0/11	1.9 U to 130 U	N/A				
Heptachlor	1/11	0.97 U to 65 U	1.9	5			
Lindane	0/11	0.96 U to 100 U	N/A				
a-Chlordane	0/11	0.93 U to 65 U	N/A				
g-Chlordane	0/11	2.2 U to 65 U	N/A				
4,4'-DDE	0/22	1.8 U to 130 U	N/A		0/13		9
4,4'-DDD	7/22	1.8 U to 130 U	88 J	9	1/14	5.5	16
4,4'-DDT	2/22	1.6 U to 150	150	IY-B-01	1/15	4.4	34
Phenols in µg/kg							
Phenol	9/22	19 U to 110	110	IY-B-06	0/22		420
2-Methylphenol	0/22	19 U to 42 U	N/A		0/22		63
4-Methylphenol	7/22	19 U to 77	77	IY-B-06	0/22		670
2,4-Dimethylphenol	1/22	19 U to 42 U	29	10	0/18		29
Pentachlorophenol	2/22	93 U to 510	510	IY-B-02	1/22	1.4	360
LPAHs in µg/kg							
2-Methylnaphthalene	20/22	19 U to 530	530	11	0/22		670
Acenaphthene	21/22	19 U to 1100	1100	10	3/22	2.2	500
Acenaphthylene	21/22	19 U to 280	280	10	0/22		1300

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Analyte	Detection Frequency	Range	Maximum Detection	Sample ID of Max. Detect.	Exceedence Frequency	Enrichment Ratio	SQO
Anthracene	22/22	150 to 5800	5800	10	6/22	6.0	960
Fluorene	22/22	33 to 1100	1100	10	3/22	2.0	540
Naphthalene	20/22	19 U to 240	240	11	0/22		2100
Phenanthrene	22/22	160 to 15000	15000	10	12/22	10.0	1500
HPAHs in μg/kg							
Benzo(a)anthracene	22/22	250 to 10000	10000	10	12/22	6.3	1600
Benzo(a)pyrene	22/22	310 J to 8900	8900	10	10/22	5.6	1600
Benzo(b)fluoranthene	22/22	440 J to 12000	12000	10			
Benzo(k)fluoranthene	22/22	310 J to 8500	8500	10			
Benzo(b&k)fluoranthene	11/11	750 to 20500	20500	10			
Benzo(g,h,i)perylene	22/22	150 J to 2600	2600	10	6/22	3.6	720
Chrysene	22/22	390 to 14000	14000	10	8/22	5.0	2800
Dibenz(a,h)anthracene	22/22	63 J to 2000	2000	10	14/22	8.7	230
Fluoranthene	22/22	380 J to 25000	25000	10	16/22	10.0	2500
Indeno(1,2,3-cd)pyrene	22/22	160 J to 4500	4500	10	9/22	6.5	690
Pyrene	22/22	540 J to 19000	19000	10	11/22	5.8	3300
Chlorinated Aromatics in μg/kg							
1,3-Dichlorobenzene	0/22	19 U to 42 U	N/A		0/22		170
1,4-Dichlorobenzene	1/22	19 U to 42	42	1	0/22		110
1,2-Dichlorobenzene	0/22	19 U to 42 U	N/A		0/22		50
1,2,4-Trichlorobenzene	1/22	19 U to 42 U	39	IY-B-01	0/22		51
Hexachloroethane	1/22	19 U to 42 U	31	1			
Hexachlorobenzene	13/22	0.61 J to 980 U	110 J	3	7/20	5.0	22
Chlorinated Aliphatics in μg/kg							
Hexachlorobutadiene	2/22	1.3 to 42 U	18 J	3	1/9	1.6	11
Phthalates in μg/kg							
Dimethylphthalate	9/22	19 U to 440	440	IY-B-01	2/22	2.8	160
Diethylphthalate	0/22	19 U to 42 U	N/A		0/22		200
Di-n-butylphthalate	16/22	19 U to 100 M	100 M	IY-B-06	0/22		1400
Butylbenzylphthalate	15/22	19 U to 2500	2500	6	1/22	2.8	900
Bis(2-Ethylhexyl)phthalate	19/22	150 to 2400	2400	10	2/22	1.8	1300
Di-n-octylphthalate	4/22	19 U to 980 U	81	IY-B-07	0/22		6200
Other Organic Compounds in μg/kg							
Benzyl Alcohol	2/11	19 U to 170	170	IY-B-06	1/11	2.3	73
Benzoic Acid	0/11	190 U to 390 U	N/A		0/11		650
Dibenzofuran	20/22	19 U to 440	440	10	0/22		540
N-Nitrosodiphenylamine	0/22	19 U to 42 U	N/A		0/18		28
Trichloroethene	4/11	0.9 J to 4	4	6			
Tetrachloroethene	3/11	0.8 J to 3	3	5	0/11		57
Ethylbenzene	0/11	0.9 U to 2.3 U	N/A		0/11		10

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Table 4-1 - Statistical Summary of Analytical Results for Bank Samples

Analyte	Detection Frequency	Range	Maximum Detection	Sample ID of Max. Detect.	Exceedence Frequency	Enrichment Ratio	SQO
m,p-Xylene	0/11	1.7 U to 4.5 U	N/A				
o-Xylene	0/11	0.9 U to 2.3 U	N/A				
Total Xylenes	11/11	1.3 to 3.4	3.4	6	0/11		40

U = not detected at detection limit indicated
J = estimated concentration
N/A = not applicable

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Table 4-2 - Statistical Summary of Analytical Results for Upper Bank Samples

Analyte	Detection Frequency	Range	Maximum Detection	Sample ID of Max. Detect.	Exceedence Frequency	Enrichment Ratio	SQO
Conventionals in percent							
Total Organic Carbon	7/7	1.6 to 5.5	5.5	IY-UB-02			
Total Solids	7/7	74.9 to 85	85	IY-UB-06			
Metals in mg/kg							
Arsenic	7/7	29.6 J to 65.8 J	65.8 J	IY-UB-05	2/7	1.2	57
Cadmium	1/7	0.58 U to 0.69 J	0.69 J	IY-UB-05	0/7		5.1
Copper	7/7	286 J to 1370 J	1370 J	IY-UB-06	4/7	3.5	390
Lead	7/7	181 J to 829 J	829 J	IY-UB-01	2/7	1.8	450
Mercury	7/7	0.18 to 1.1	1.1	IY-UB-01	2/7	1.9	0.59
Zinc	7/7	504 J to 3480 J	3480 J	IY-UB-05	7/7	8.5	410
Pesticide/PCBs in µg/kg							
Aroclor 1016	0/7	19 U to 1000 U	N/A				
Aroclor 1221	0/7	37 U to 2000 U	N/A				
Aroclor 1232	0/7	19 U to 1000 U	N/A				
Aroclor 1242	0/7	19 U to 1000 U	N/A				
Aroclor 1248	0/7	19 U to 1000 U	N/A				
Aroclor 1254	0/7	19 U to 1000 U	N/A				
Aroclor 1260	7/7	35 to 32000	32000	IY-UB-01			
Total PCBs	7/7	35 to 32000	32000	IY-UB-01	2/7	106.7	300
4,4'-DDE	0/7	1.9 U to 100 U	N/A		0/5		9
4,4'-DDD	0/7	1.9 U to 100 U	N/A		0/5		16
4,4'-DDT	5/7	6.2 to 590 U	37	IY-UB-04	1/5	1.1	34
Phenols in µg/kg							
2,4-Dimethylphenol	0/7	19 U to 190 U	N/A		0/1		29
2-Methylphenol	0/7	19 U to 190 U	N/A		0/5		63
4-Methylphenol	4/7	20 J to 190 U	56 M	IY-UB-05	0/7		670
Pentachlorophenol	0/7	93 U to 970 U	N/A		0/5		360
Phenol	4/7	23 J to 190 U	91	IY-UB-06	0/7		420
LPAHs in µg/kg							
2-Methylnaphthalene	3/7	37 U to 240	240	IY-UB-03	0/7		670
Acenaphthene	7/7	41 to 340	340	IY-UB-03	0/7		500
Acenaphthylene	5/7	39 U to 190 U	120	IY-UB-01	0/7		1300
Anthracene	7/7	84 M to 1000	1000	IY-UB-02	1/7	1.0	960
Fluorene	6/7	39 U to 420	420	IY-UB-03	0/7		540
Naphthalene	5/7	46 to 190 U	170	IY-UB-03	0/7		2100
Phenanthrene	7/7	390 to 3700	3700	IY-UB-02	3/7	2.5	1500
HPAHs in µg/kg							
Benzo(a)anthracene	7/7	230 to 2000	2000	IY-UB-02	1/7	1.3	1600
Benzo(a)pyrene	7/7	230 to 1200	1200	IY-UB-02	0/7		1600
Benzo(b)fluoranthene	7/7	230 to 1600	1600	IY-UB-02			
Benzo(k)fluoranthene	7/7	210 M to 1500	1500	IY-UB-01			
Benzo(g,h,i)perylene	7/7	200 to 730 M	730 M	IY-UB-02	1/7	1.0	720

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Table 4-2 - Statistical Summary of Analytical Results for Upper Bank Samples

Analyte	Detection Frequency	Range	Maximum Detection	Sample ID of Max. Detect.	Exceedence Frequency	Enrichment Ratio	SQO
Chrysene	7/7	340 to 2600	2600	IY-UB-02	0/7		2800
Dibenz(a,h)anthracene	6/7	50 M to 240 M	240 M	IY-UB-04	1/7	1.0	230
Fluoranthene	7/7	520 to 4200	4200	IY-UB-01	2/7	1.7	2500
Indeno(1,2,3-cd)pyrene	7/7	200 to 720	720	IY-UB-01	1/7	1.0	690
Pyrene	7/7	440 to 4100	4100	IY-UB-02	1/7	1.2	3300
Chlorinated Aromatics in µg/kg							
1,3-Dichlorobenzene	0/7	19 U to 190 U	N/A		0/6		170
1,4-Dichlorobenzene	0/7	19 U to 190 U	N/A		0/6		110
1,2-Dichlorobenzene	0/7	19 U to 190 U	N/A		0/5		50
1,2,4-Trichlorobenzene	0/7	19 U to 190 U	N/A		0/5		51
Hexachlorobenzene	1/7	.93 U to 51 U	13	IY-UB-04	0/5		22
Chlorinated Aliphatics in µg/kg							
Hexachlorobutadiene	1/7	1.1 UJ to 51 U	39	IY-UB-10	1/5	3.5	11
Phthalates in µg/kg							
Dimethylphthalate	1/7	19 U to 1200	1200	IY-UB-02	1/7	7.5	160
Diethylphthalate	0/7	19 U to 190 U	N/A		0/7		200
Di-n-butylphthalate	4/7	39 U to 190 U	91	IY-UB-10	0/7		1400
Butylbenzylphthalate	2/7	28 M to 190 U	40 M	IY-UB-05	0/7		900
Bis(2-Ethylhexyl)phthalate	7/7	300 to 510	510	IY-UB-06	0/7		1300
Di-n-octylphthalate	2/7	19 M to 190 U	50 M	IY-UB-05	0/7		6200
Other Organic Compounds in µg/kg							
Benzyl Alcohol	0/7	19 U to 190 U	N/A		0/5		73
Benzoic Acid	0/7	190 U to 1900 U	N/A		0/5		650
Dibenzofuran	5/7	38 to 190 U	120	IY-UB-03	0/7		540
N-Nitrosodiphenylamine	0/7	19 U to 190 U	N/A		0/1		28
Hexachloroethane	0/7	19 U to 190 U	N/A				

U = not detected at detection limit indicated
J = estimated concentration
N/A = not applicable

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Table 4-3 - Statistical Summary of Analytical Results for Surface Side Slope Samples

Analyte	Detection Frequency	Range	Maximum Detection	Sample ID of Max. Detect.	Exceedence Frequency	Enrichment Ratio	SQO
Conventionals in percent							
Total Organic Carbon	5/5	1.9 to 2.4	2.4	IY-S-04			
Total Solids	5/5	45.4 to 47.5	47.5	IY-S-02			
Metals in mg/kg							
Antimony	7/8	0.2 U to 29 J	29 J	9A	0/8		150
Arsenic	16/16	13.2 to 45 J	45 J	11A	0/16		57
Cadmium	12/16	0.37 J to 8.6	8.6	IY-S-02	1/16	1.7	5.1
Chromium	11/11	26.5 to 131	131	9A			
Copper	16/16	90.3 J to 487 J	487 J	IY-S-01	1/16	1.2	390
Lead	16/16	39.2 J to 391 J	391 J	9A	0/16		450
Mercury	16/16	0.12 J to .53	0.53	IY-S-01	0/16		0.59
Nickel	11/11	20 to 79	79	9A	0/11		140
Silver	11/11	0.22 J to 0.59 J	0.59 J	3A	0/11		6.1
Zinc	16/16	131 J to 5130 J	5130 J	IY-S-02	4/16	12.5	410
Pesticide/PCBs in µg/kg							
Aroclor 1016	0/16	18 U to 200 U	N/A				
Aroclor 1221	0/16	37 U to 400 U	N/A				
Aroclor 1232	0/16	18 U to 200 U	N/A				
Aroclor 1242	0/16	18 U to 200 U	N/A				
Aroclor 1248	0/16	18 U to 200 U	N/A				
Aroclor 1254	2/16	18 U to 1600 J	1600 J	9A			
Aroclor 1260	10/16	18 U to 1300 J	1300 J	9A			
Total PCBs	12/16	37 U to 3440	3440	9A	6/16	11.5	300
Aldrin	0/11	0.94 U to 38 U	N/A				
Dieldrin	0/11	1.9 U to 21 U	N/A				
Heptachlor	0/11	0.93 U to 16 U	N/A				
Lindane	0/11	0.9 U to 9.8 U	N/A				
a-Chlordane	0/11	0.93 U to 22 U	N/A				
g-Chlordane	0/11	6.7 U to 30 U	N/A				
4,4'-DDE	0/16	1.8 U to 30 U	N/A		0/13		9
4,4'-DDD	11/16	3.1 to 22 J	22 J	9A	2/15	1.4	16
4,4'-DDT	1/16	1.8 U to 48 U	35 J	3B	1/14	1.0	34
Phenols in µg/kg							
Phenol	9/16	25 to 580 U	240 J	1A	0/15		420
2-Methylphenol	0/16	19 U to 580 U	N/A		0/11		63
4-Methylphenol	3/16	19 U to 200 U	40 J	3A	0/16		670
2,4-Dimethylphenol	0/16	19 U to 580 U	N/A		0/3		29
Pentachlorophenol	0/16	96 U to 2900 U	N/A		0/11		360
LPAHs in µg/kg							
2-Methylnaphthalene	16/16	45 J to 8700	8700	9B	1/16	13.0	670
Acenaphthene	16/16	71 to 9900	9900	9B	3/16	19.8	500
Acenaphthylene	15/16	96 to 410 J	410 J	5B	0/16		1300

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Table 4-3 - Statistical Summary of Analytical Results for Surface Side Slope Samples

Analyte	Detection Frequency	Range	Maximum Detection	Sample ID of Max. Detect.	Exceedence Frequency	Enrichment Ratio	SQO
Anthracene	16/16	720 J to 8600 J	8600 J	5B	12/16	9.0	960
Fluorene	16/16	200 to 9800	9800	9B	5/16	18.1	540
Naphthalene	16/16	56 J to 11000	11000	9B	1/16	5.2	2100
Phenanthrene	16/16	820 to 48000	48000	9B	11/16	32.0	1500
HPAHs in µg/kg							
Benzo(a)anthracene	16/16	1400 to 8700	8700	9B	14/16	5.4	1600
Benzo(a)pyrene	16/16	1300 to 6700	6700	9B	14/16	4.2	1600
Benzo(b)fluoranthene	16/16	1700 to 6100	6100	9B			
Benzo(k)fluoranthene	16/16	1200 to 5500 J	5500 J	7A			
Benzo(b&k)fluoranthene	11/11	3600 to 11100	11100	9B			
Benzo(g,h,i)perylene	16/16	410 J to 1800	1800	9B	7/16	2.5	720
Chrysene	16/16	1400 to 10000	10000	9B	11/16	3.6	2800
Dibenz(a,h)anthracene	16/16	220 J to 1600	1600	9B	14/16	7.0	230
Fluoranthene	16/16	2500 J to 31000	31000	IY-S-04	15/16	12.4	2500
Indeno(1,2,3-cd)pyrene	16/16	660 J to 2500 J	2500 J	9B	15/16	3.6	690
Pyrene	16/16	2200 to 26000 J	26000 J	9B	14/16	7.9	3300
Chlorinated Aromatics in µg/kg							
1,3-Dichlorobenzene	0/16	19 U to 580 U	N/A		0/13		170
1,4-Dichlorobenzene	1/16	19 to 580 U	19	IY-S-02	0/13		110
1,2-Dichlorobenzene	0/16	19 U to 580 U	N/A		0/10		50
1,2,4-Trichlorobenzene	1/16	19 U to 580 U	52 J	1A	1/10	1.0	51
Hexachloroethane	2/16	19 U to 2000 J	2000 J	5A			
Hexachlorobenzene	5/16	0.94 U to 580 U	380 J	1A	2/7	17.3	22
Chlorinated Aliphatics in µg/kg							
Hexachlorobutadiene	3/16	7.7 U to 2100 J	2100 J	1A	2/6	190.9	11
Phthalates in µg/kg							
Dimethylphthalate	4/16	19 U to 580 U	99 J	3A	0/13		160
Diethylphthalate	0/16	19 U to 580 U	N/A		0/15		200
Di-n-butylphthalate	4/16	19 U to 580 U	66 J	3A	0/16		1400
Butylbenzylphthalate	3/16	19 U to 580 U	100	9A	0/16		900
Bis(2-Ethylhexyl)phthalate	16/16	480 to 3600	3600	IY-S-03	2/16	2.8	1300
Di-n-octylphthalate	0/16	19 U to 580 U	N/A		0/16		6200
Other Organic Compounds in µg/kg							
Benzyl Alcohol	1/5	19 U to 200 U	50	IY-S-04	0/4		73
Benzoic Acid	0/5	190 U to 2000 U	N/A		0/4		650
Dibenzofuran	16/16	95 to 6000	6000	9B	3/16	11.1	540
N-Nitrosodiphenylamine	0/16	19 U to 580 U	N/A		0/3		28
Trichloroethene	2/11	1.3 U to 66 J	66 J	1A			
Tetrachloroethene	1/11	1.3 U to 140 J	140 J	1A	1/11	2.5	57
Ethylbenzene	1/11	1.3 U to 3.6 U	1.5 J	11B	0/11		10

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Table 4-3 - Statistical Summary of Analytical Results for Surface Side Slope Samples

Analyte	Detection Frequency	Range	Maximum Detection	Sample ID of Max. Detect.	Exceedence Frequency	Enrichment Ratio	SQO
m,p-Xylene	0/11	2.6 U to 7.2 U	N/A				
o-Xylene	0/11	1.3 U to 3.6 U	N/A				
Total Xylenes	11/11	2 to 5.4	5.4	1A	0/11		40

U = not detected at detection limit indicated
J = estimated concentration
N/A = not applicable

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Table 4-4 - Statistical Summary of Analytical Results for Subsurface Side Slope Samples

Analyte	Detection Frequency	Range	Maximum Detection	Sample ID of Max. Detect.	Exceedence Frequency	Enrichment Ratio	SQO
Conventionals in percent							
Total Organic Carbon	12/12	2.1 to 4.1	4.1	IY-C-01-S2			
Total Solids	12/12	45.9 to 57.2	57.2	IY-C-01-S2			
Metals in mg/kg							
Antimony	19/20	0.7 U to 69 J	69 J	9A	0/20		150
Arsenic	28/28	3.6 J to 200	200	7B	7/28	3.5	57
Cadmium	26/28	0.47 J to 7.5	7.5	9A	2/28	1.5	5.1
Chromium	22/22	10.3 J to 253 J	253 J	11A			
Copper	28/28	32.1 J to 1920	1920	3A	6/28	4.9	390
Lead	28/28	22 J to 1940 J	1940 J	9A	9/28	4.3	450
Mercury	28/28	0.09 J to 3 J	3 J	IY-C-01-S2	14/28	5.1	0.59
Nickel	22/22	17 J to 203	203	9A	1/22	1.5	140
Silver	21/22	0.06 U to 2.3	2.3	3A	0/22		6.1
Zinc	28/28	36 J to 2330	2330	9A	13/28	5.7	410
Pesticide/PCBs in µg/kg							
Aroclor 1016	0/34	18 U to 1800 U	N/A				
Aroclor 1221	0/34	36 U to 3600 U	N/A				
Aroclor 1232	0/34	18 U to 1800 U	N/A				
Aroclor 1242	0/34	18 U to 1800 U	N/A				
Aroclor 1248	0/34	18 U to 1800 U	N/A				
Aroclor 1254	27/34	19 U to 2500 J	2500 J	3B			
Aroclor 1260	28/34	19 U to 2600 J	2600 J	7A			
Total PCBs	33/34	37 U to 8450	8450	7A	24/34	28.2	300
Aldrin	0/22	0.91 U to 89 U	N/A				
Dieldrin	0/22	1.8 U to 180 U	N/A				
Heptachlor	0/22	0.95 U to 240 U	N/A				
Lindane	0/22	0.96 U to 89 U	N/A				
a-Chlordane	0/22	0.92 U to 96 U	N/A				
g-Chlordane	0/22	0.95 U to 89 U	N/A				
4,4'-DDE	2/34	1.9 U to 360 U	21 J	IY-C-05-S2	1/14	2.3	9
4,4'-DDD	16/34	1.9 U to 180 U	92 J	9A	12/23	5.8	16
4,4'-DDT	5/34	1.9 U to 180 U	64	IY-C-01-S2	1/24	1.9	34
Phenols in µg/kg							
Phenol	6/34	38 U to 380 U	310 J	1A	0/34		420
2-Methylphenol	3/34	20 U to 650 J	650 J	1A	2/27	10.3	63
4-Methylphenol	5/34	20 U to 2000 U	870 J	5A	1/32	1.3	670
2,4-Dimethylphenol	5/34	20 U to 2100 J	2100 J	1A	5/6	72.4	29
Pentachlorophenol	0/34	98 U to 760 U	N/A		0/26		360
LPAHs in µg/kg							
2-Methylnaphthalene	25/34	38 U to 3500 J	3500 J	1A	7/34	5.2	670
Acenaphthene	31/34	38 U to 8800	8800	7A	15/34	17.6	500
Acenaphthylene	24/34	38 U to 280	280	IY-C-03-S2	0/34		1300

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Table 4-4 - Statistical Summary of Analytical Results for Subsurface Side Slope Samples

Analyte	Detection Frequency	Range	Maximum Detection	Sample ID of Max. Detect.	Exceedence Frequency	Enrichment Ratio	SQO
Anthracene	34/34	160 to 5300 J	5300 J	1A	15/34	5.5	960
Fluorene	34/34	56 to 5200 J	5200 J	1A	15/34	9.6	540
Naphthalene	34/34	62 to 43000 J	43000 J	1A	4/34	20.5	2100
Phenanthrene	34/34	300 to 25000 J	25000 J	1A	16/34	16.7	1500
HPAHs in µg/kg							
Benzo(a)anthracene	34/34	500 to 6100	6100	IY-C-03-S2	13/34	3.8	1600
Benzo(a)pyrene	34/34	290 J to 7500	7500	IY-C-03-S2	16/34	4.7	1600
Benzo(a)pyrene	34/34	290 J to 7500	7500	IY-C-05-S2	16/34	4.7	1600
Benzo(b)fluoranthene	34/34	300 J to 6100 J	6100 J	11B			
Benzo(k)fluoranthene	34/34	390 J to 4000	4000	IY-C-01-S2			
Benzo(b&k)fluoranthene	22/22	690 to 10000	10000	11B			
Benzo(g,h,i)perylene	32/34	150 U to 3400	3400	IY-C-03-S2	14/34	4.7	720
Chrysene	34/34	900 J to 8200 J	8200 J	11B	12/34	2.9	2800
Dibenz(a,h)anthracene	32/34	140 to 1800	1800	IY-C-03-S2	26/34	7.8	230
Fluoranthene	34/34	710 J to 18000 J	18000 J	1A	16/34	7.2	2500
Indeno(1,2,3-cd)pyrene	32/34	150 U to 3300	3300	IY-C-03-S2	22/34	4.8	690
Pyrene	34/34	1200 J to 23000	23000	IY-C-01-S2	23/34	7.0	3300
Chlorinated Aromatics in µg/kg							
1,3-Dichlorobenzene	1/34	20 U to 380 U	56 J	3B	0/33		170
1,4-Dichlorobenzene	1/34	20 U to 380 U	50 J	5B	0/33		110
1,2-Dichlorobenzene	0/34	20 U to 380 U	N/A		0/11		50
1,2,4-Trichlorobenzene	7/34	20 U to 380 J	380 J	3B	7/16	7.5	51
Hexachloroethane	0/22	38 U to 380 U	N/A				
Hexachlorobenzene	27/44	5.5 to 5600 J	5600 J	1A	17/27	254.5	22
Chlorinated Aliphatics in µg/kg							
Hexachlorobutadiene	21/44	0.96 UJ to 72000 J	72000 J	1A	15/22	6545.5	11
Phthalates in µg/kg							
Dimethylphthalate	1/34	34 to 150 U	34	IY-C-01-S1	0/34		160
Diethylphthalate	0/34	20 U to 150 U	N/A		0/34		200
Di-n-butylphthalate	4/34	20 U to 210	210	7A	0/34		1400
Butylbenzylphthalate	7/34	20 U to 420 U	120 J	7A	0/34		900
Bis(2-Ethylhexyl)phthalate	34/34	200 J to 3300	3300	IY-C-05-S2	10/34	2.5	1300
Di-n-octylphthalate	2/34	20 U to 420 U	160 J	3B	0/34		6200
Other Organic Compounds in µg/kg							
Benzyl Alcohol	0/12	20 U to 60 U	N/A		0/12		73
Benzoic Acid	0/12	200 U to 600 U	N/A		0/12		650
Dibenzofuran	33/34	38 to 3900	3900	7A	9/34	7.2	540
N-Nitrosodiphenylamine	0/34	20 U to 4600 U	N/A		0/1		28
Trichloroethene	13/22	1.1 to 690 J	690 J	1A			
Tetrachloroethene	4/22	1.1 J to 36000 J	36000 J	1A	2/22	631.6	57

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Table 4-4 - Statistical Summary of Analytical Results for Subsurface Side Slope Samples

Analyte	Detection Frequency	Range	Maximum Detection	Sample ID of Max. Detect.	Exceedence Frequency	Enrichment Ratio	SQO
Ethylbenzene	14/22	1.1 U to 280 J	280 J	1A	9/22	28.0	10
m,p-Xylene	13/22	2.1 U to 400 J	400 J	1A			
o-Xylene	12/22	1.1 U to 170 J	170 J	1A			
Total Xylenes	22/22	1.6 to 570	570	1A	4/22	14.3	40

U = not detected at detection limit indicated
J = estimated concentration
N/A = not applicable

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Table 4-5 - Ranking of Chemical Constituents in Surface Sediment Samples

Combined Score	Percent Exceedence	Maximum Enrichment	Analyte	SQO	Exceedence Ratio	Percent Exceedence	Maximum Enrichment
9	5	4	Phenanthrene	1500	26/45	57.78	32.00
10	8	2	Total PCBs	300	21/45	46.67	106.67
12	2	10	Zinc	410	30/45	66.67	12.59
12	1	11	Fluoranthene	2500	33/45	73.33	12.40
13	10	3	Copper	390	17/45	37.78	39.49
15	14	1	Hexachlorobutadiene	11	4/20	20.00	190.91
17	3	14	Dibenz(a,h)anthracene	230	29/45	64.44	8.70
19	11	8	LPAHs	5200	15/45	33.33	16.43
20	13	7	Hexachlorobenzene	22	9/32	28.00	17.27
20	5	15	Pyrene	3300	26/45	57.78	7.88
21	16	5	Acenaphthene	500	6/45	13.33	19.80
21	15	6	Fluorene	540	8/45	17.78	18.15
22	9	13	Anthracene	960	19/45	42.22	8.96
22	3	19	HPAHs	17000	29/45	64.44	6.26
24	6	18	Indeno(1,2,3-cd)pyrene	690	25/45	55.56	6.52
24	4	20	Benzo(a)anthracene	1600	27/45	60.00	6.25
28	7	21	Total Benzofluoranthenes	3600	24/45	53.33	5.69
29	7	22	Benzo(a)pyrene	1600	24/45	53.33	5.56
32	20	12	Dibenzofuran	540	3/45	6.67	11.11
33	16	17	Lead	450	6/45	13.33	7.38
34	25	9	2-Methylnaphthalene	670	1/45	2.22	12.99
34	9	25	Chrysene	2800	19/45	42.22	5.00
35	19	16	Dimethylphthalate	160	3/42	7.14	7.50
39	12	27	Benzo(g,h,i)perylene	720	14/45	31.11	3.61
41	18	23	4,4'-DDD	16	3/34	8.82	5.50
44	18	26	4,4'-DDT	34	3/34	8.82	4.41
46	17	29	Bis(2-Ethylhexyl)phthalate	1300	4/45	8.89	2.77
47	16	31	Mercury	0.59	6/45	13.33	2.34
48	15	33	Arsenic	57	8/45	17.78	2.04
49	25	24	Naphthalene	2100	1/45	2.22	5.24
52	22	30	Tetrachloroethene	57	1/22	4.55	2.46
53	25	28	Butylbenzylphthalate	900	1/45	2.22	2.78
53	21	32	Benzyl Alcohol	73	1/20	5.00	2.33
58	22	36	Silver	6.1	1/22	4.55	1.13
59	25	34	Cadmium	5.1	1/45	2.22	1.69
59	24	35	Pentachlorophenol	360	1/38	2.63	1.42
59	22	37	Nickel	140	1/22	4.55	1.03
61	23	38	1,2,4-Trichlorobenzene	51	1/37	2.70	1.02

Key Constituent for Pre-Remedial Design

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Table 4-6 - Ranking of Chemical Constituents in Subsurface Sediment Samples

Combined Score	Percent Exceedence	Maximum Enrichment	Analyte	SQO	Exceedence Ratio	Percent Exceedence	Maximum Enrichment
5	4	1	Hexachlorobutadiene	11	15/22	68.18	6545.45
5	1	4	2,4-Dimethylphenol	29	5/6	83.33	72.41
8	3	5	Total PCBs	300	24/34	70.59	28.17
10	7	3	Hexachlorobenzene	22	17/27	62.96	254.55
16	2	14	Dibenz(a,h)anthracene	230	26/34	76.47	7.83
20	11	9	Phenanthrene	1500	16/34	47.06	16.67
21	13	8	Acenaphthene	500	15/34	44.12	17.60
21	11	10	LPAHs	5200	16/34	47.06	15.71
22	16	6	Ethylbenzene	10	9/22	40.91	28.00
23	5	18	Pyrene	3300	23/34	67.65	6.97
26	13	13	Fluorene	540	15/34	44.12	9.63
28	11	17	Fluoranthene	2500	16/34	47.06	7.20
28	9	19	4,4'-DDD	16	12/23	52.17	5.75
29	27	2	Tetrachloroethene	57	2/22	9.09	631.58
29	14	15	1,2,4-Trichlorobenzene	51	7/16	43.75	7.45
31	6	25	Indeno(1,2,3-cd)pyrene	690	22/34	64.71	4.78
32	12	20	Zinc	410	13/28	46.43	5.68
33	26	7	Naphthalene	2100	4/34	11.76	20.48
33	10	23	Mercury	0.59	14/28	50.00	5.08
34	13	21	Anthracene	960	15/34	44.12	5.52
36	25	11	Total Xylenes	40	4/22	18.18	14.25
37	21	16	Dibenzofuran	540	9/34	26.47	7.22
37	8	29	HPAHs	17000	21/34	61.76	4.16
38	11	27	Benzo(a)pyrene	1600	16/34	47.06	4.69
40	28	12	2-Methylphenol	63	2/27	7.41	10.32
41	15	26	Benzo(g,h,i)perylene	720	14/34	41.18	4.72
44	11	33	Total Benzofluoranthene	3600	16/34	47.06	2.78
46	24	22	2-Methylnaphthalene	670	7/34	20.59	5.22
47	23	24	Copper	390	6/28	21.43	4.92
47	19	28	Lead	450	9/28	32.14	4.31
47	17	30	Benzo(a)anthracene	1600	13/34	38.24	3.81
50	18	32	Chrysene	2800	12/34	35.29	2.93
53	22	31	Arsenic	57	7/28	25.00	3.51
54	20	34	Bis(2-Ethylhexyl)phthalate	1300	10/34	29.41	2.54
64	29	35	4,4'-DDE	9	1/14	7.14	2.33
66	29	37	Cadmium	5.1	2/28	7.14	1.47
67	31	36	4,4'-DDT	34	1/24	4.17	1.88
68	30	38	Nickel	140	1/22	4.55	1.45
71	32	39	4-Methylphenol	670	1/32	3.13	1.30

Key Constituent for Pre-Remedial Design

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5.0 NATURE AND EXTENT OF CONTAMINATION

This section describes the distribution of key constituents in surface and subsurface sediments beneath Pier 25 on the Hylebos Waterway side of the Industrial Yard, and bank sediments along the Commencement Bay side of the Industrial Yard. Based on the distribution of these key constituents, their magnitude of enrichment above SQOs, and the co-occurrence of certain constituents, Sediment Management Areas (SMAs) are developed for use in future remedial design efforts, as described in Section 6.

5.1 Distribution of Constituents of Concern—Surface Sediment

The distribution of constituents of concern in surface sediments—total PCBs, zinc, copper, mercury, phenanthrene, fluoranthene, dibenz(a,h)anthracene, and hexachlorobutadiene—are presented on Figures 5-1 through 5-8, respectively. These figures were constructed using data collected by the Port of Tacoma adjacent to the former AK-WA Shipyard site, as well as data collected concurrently by Oxychem adjacent to the Tyson Seafoods site (CRA, 1998). In general, the concentration of at least one constituent exceeded its SQO in the entire underpier area. Brief descriptions of the spatial distributions of key constituents are presented below.

It should be noted that upper bank samples were collected from isolated pockets of sediment within the riprap. Therefore, although the distribution of exceedences is presented as being uniform throughout the bank area, i.e., above 0 foot MLLW, it is more likely to be in discontinuous patches where sediment has collected in the interstices of the riprap.

PCBs. The distribution of ERs for total PCBs is depicted on Figure 5-1. Surface sediment concentrations of total PCBs greater than ten times the SQO are present in two areas under Pier 25. Bank sediments within a small area near the northwestern debris pile (IY-B-05) contained PCBs at a maximum ER of 24. A second larger area under the central pier area (IY-UB-01) contained PCBs with a maximum ER of 107. Exceedences of PCBs at the Industrial Yard are present mainly on the bank and upper bank, but locally extend over the side slope (Oxychem sample 9A). An area of lower enrichments extends along the southern bank with a maximum ER of 2.8 (Oxychem sample 3).

Total Metals. Distributions of copper, mercury, and zinc are presented on Figures 5-2, 5-3, and 5-4, respectively. Most of the centrally located areas which contain exceedences of metals are collocated with PCB exceedence areas. Zinc (in sample IY-B-02) and copper (in Oxychem sample 9) contain enrichments of

12.6 and 38.5, respectively, in the central part of the pier. Concentrations of copper and zinc are also present with ERs greater than 3.0 in the upper bank area near the mouth of the waterway; copper and zinc commonly co-occur at the site. In addition, lesser enrichments of copper and zinc (ER < 2.5) extend across the Commencement Bay side of the bank, along the dry dock area of the former AK-WA Shipyard. Zinc exceedences extend out to greater depths on the side slope near sample location IY-S-02 (ER = 12.5). Isolated areas with zinc ERs greater than 3 are also present in bank samples in the southernmost portion of the study area; this area contains lesser enrichments of zinc and mercury as well, especially in Oxychem sample 3.

Phenanthrene. The extent of phenanthrene exceedences is presented on Figure 5-5. Phenanthrene concentrations peak in the central part of the pier, reaching 10 and 32 times the SQO in Oxychem samples 10 and 9B, respectively. Concentrations generally increase with water depth, and maximum concentrations are usually found near the pierhead line (including Oxychem samples 1A and 5B with enrichment ratios of 4.5 and 8.0, respectively). However, phenanthrene enrichments decrease rapidly beyond the pierhead line, evidenced by HCC samples which are well below the SQO. Although phenanthrene exhibits more extreme enrichments in a centrally located hot spot, elsewhere on the lower slope fluoranthene drives the enrichment ratio for PAHs, as discussed below.

Fluoranthene. The extent of the fluoranthene exceedences is presented on Figure 5-6. Fluoranthene enrichments are commonly found along the side slope under Pier 25, peaking at ten times the SQO in several samples (including samples IY-S-04, and Oxychem samples 5B, 9B, and 10, with enrichment ratios of 12.4, 9.2, 11.2, and 10.0). Concentrations appear to increase with water depth, with maximum concentrations usually found near the pierhead line. However, fluoranthene enrichments decrease rapidly beyond the pierhead line, evidenced by HCC samples in the waterway which are below the SQO (including samples 5101, HY-04, 5103, and HY-06). Low level fluoranthene enrichments also occur along the Commencement Bay side of the former AK-WA Shipyard, with a small area of higher enrichment below Pier 24 (IY-B-10, ER = 4.0).

Dibenz(a,h)anthracene. The extent of the dibenz(a,h)anthracene exceedences is presented on Figure 5-7. The distribution of dibenz(a,h)anthracene in surface sediments largely mimics the distribution of fluoranthene, that is, it is mainly found on the side slope areas. Like fluoranthene, the concentrations of dibenz(a,h)anthracene appear to increase with depth toward the pierhead line in many places, although the highest enrichment was found in a bank sample (Oxychem sample 10; ER = 8.7). On the side slope, the highest enrichments are detected in sample IY-S-04, and Oxychem samples 7A and 9B, with enrichment ratios of 4.2, 5.7, and 7.0, respectively. In nearly all of the surface sediment samples, however, the enrichment ratio for fluoranthene is greater than that for dibenz(a,h)anthracene.

Hexachlorobutadiene. The extent of the hexachlorobutadiene (HCBD) exceedences is presented on Figure 5-8. Extreme enrichments at 190 times and 53 times the SQO are found in Oxychem samples 1A and 5B near the southeastern property boundary, and adjacent to HCC Area 5106 which is known to contain high concentrations of HCBD and other chlorinated compounds. It is difficult to accurately map the northwestern extent of this hot spot, however, because the HCBD detection limits in the Oxychem investigation are routinely elevated above the SQO, 4 to 18 times the SQO. Thus, the contours on Figure 5-8 are extrapolated mainly on the basis of detection limits. It is possible that better quantitation can be achieved for HCBD in the pesticide fraction, rather than the semivolatile fraction which was reported by Oxychem (see Appendix E). Although the highest enrichments are detected along the southeastern portion of the side slope beneath Pier 25, an HCBD enrichment at 3.5 times the SQO was also found on the upper bank beneath Pier 24 on the Commencement Bay side of the Industrial Yard (IY-UB-10).

5.2 Distribution of Key Constituents—Subsurface Sediments

This section describes the vertical extent of SQO exceedences for chemical constituents in subsurface sediment within the Industrial Yard. Subsurface sediments are restricted to side slope areas below 0 feet MLLW, the approximate base of riprap. The vertical extent of contamination is based on subsurface sediment sampling completed at seventeen locations within the Industrial Yard by the Port during this study (sample locations IY-C-01 through IY-C-06) and by Oxychem in a concurring study (Oxychem samples 1A through 11B; CRA, 1998; Appendix E). Samples for chemical analysis were collected from selected cores to depths of 3 feet below mudline.

The enrichment ratios for key constituents exceeding SQOs are posted with depth information on Figure 5-9. Brief descriptions of the vertical distribution of key constituents on the side slope are presented below. It should be noted that in many cases the depth of contamination in subsurface sediments has not been determined, and SQO exceedences extend to the maximum depths of the cores.

Copper. One localized area under Pier 25 contained copper concentrations nearly five times the SQO. Oxychem sample 3A-S2, near the northeast debris pile, contained an enrichment ratio of 4.9, at least to a depth of 3 feet. In addition, a few samples in the central and northwestern portions of the side slope had low-level copper concentrations between 1.1 and 1.6 times the SQO (IY-C-05, S1; IY-C-01, S1; 9A - S2).

Mercury. The highest concentrations of mercury in side slope sediments were detected in the central pier area, with a maximum enrichment ratio of 5.1 in sample IY-C-01-S2, to a depth of at least 3 feet. Several other samples from the central pier area contained mercury enrichments between 2.4 and 3.9 times the SQO (including Oxychem samples 9A-S1, 9A-S2, 11A-S1, and 11A-S2), and an isolated sample (IY-C-05-S2) from the northwestern part of the underpier area exceeded the SQO by 2.5 times. Mercury concentrations were consistently higher on the upper part of the side slope, and decreased toward the pierhead line. No consistent vertical trends (i.e., increasing or decreasing concentrations over time) were discerned in the core subsamples.

Zinc. The highest zinc enrichments also clustered in the central pier area, more or less coincident with mercury enrichments. The Oxychem samples 9A-S1 and 9A-S2 contained zinc enrichments greater than 5 times the SQO, to a depth of at least 3 feet. Several other samples from the central pier area contained mercury enrichments between 2.4 and 3.7 times the SQO (including Oxychem samples 7A-S1, 7A-S2, 11A-S1, and 11A-S2). Like mercury, zinc enrichments were consistently higher on the upper part of the side slope, and decreased toward the pierhead line.

Dibenz(a,h)anthracene. The highest enrichments of dibenz(a,h)anthracene were detected in the northwestern part of the underpier area on the upper side slope. In particular, samples IY-C-01-S2, IY-C-03-S2, and IY-C-05-S2 contained enrichments of 7.0, 7.8, and 7.4 times the SQO, respectively. These three enrichments consistently occurred in the lower sections of the cores, extending to at least 3 feet depth. Somewhat lower enrichments, between 3 and 5 times the SQO, were detected in samples 9B-S1, 11A-S1, 11B-S1, and IY-C-02-S1, but at these locations the highest concentrations were detected in the upper sections of the cores. Thus, the vertical trends in the core subsamples were not consistent across the study area.

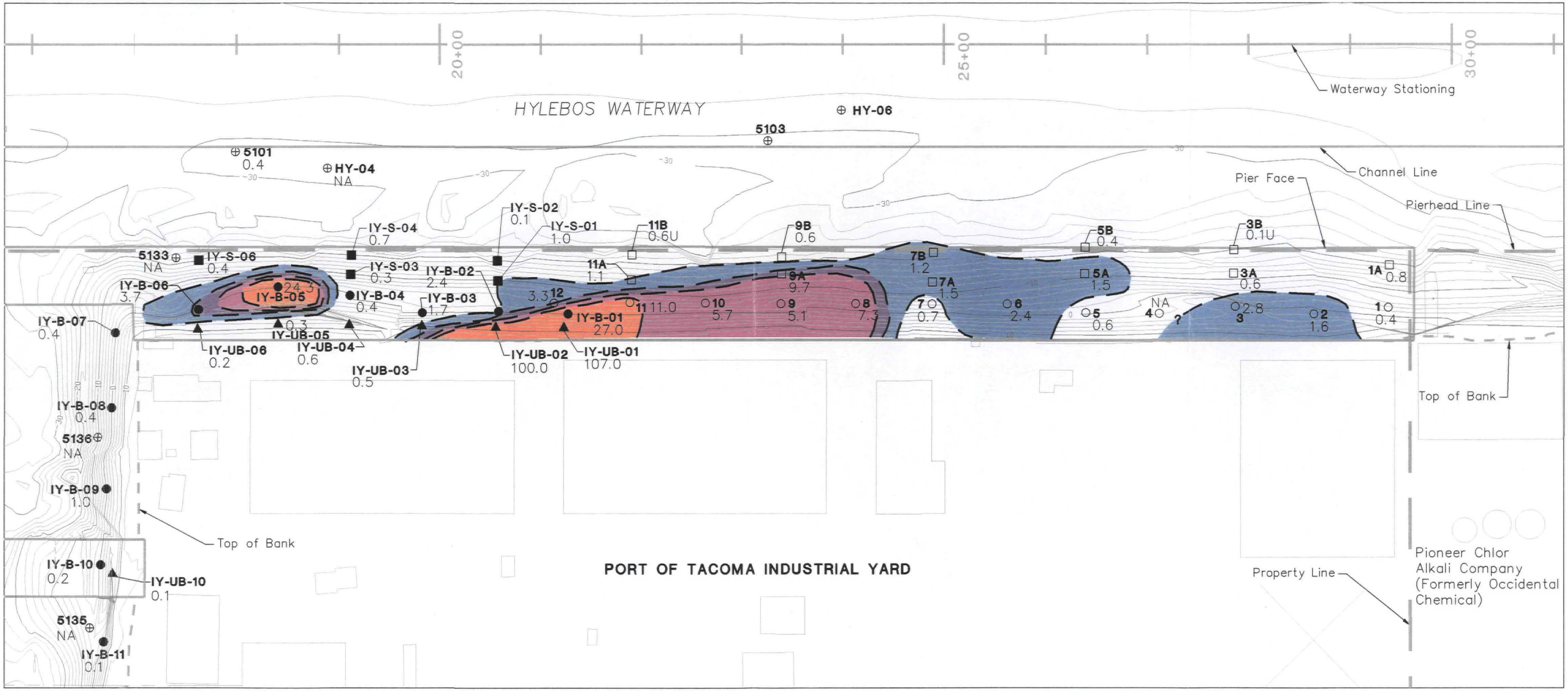
Phenanthrene. Elevated concentrations of phenanthrene were detected in the northwestern part of the underpier area, co-occurring with similar enrichments of dibenz(a,h)anthracene. In particular, samples IY-C-01-S2, IY-C-02-S1, IY-C-03-S2, and IY-C-05-S2 contained fluoranthene enrichment ratios of 6.7, 3.7, 7.3 and 10.0, respectively. On the upper part of the side slope (along the elevation -10 feet MLLW contour), phenanthrene concentrations increase significantly with depth and maximum concentrations occur in the bottom of the cores. In contrast, the sediments on the southeastern part of the side slope, near the property boundary with Pioneer Chlor Alkali Company, is dominated by phenanthrene enrichments which are significantly higher than dibenz(a,h)anthracene enrichments, suggesting a different and lighter weight PAH signature. Samples 1A-S1, 1A-S2, 5A-S1, and 5A-S2 contained phenanthrene enrichments of 8.0, 16.7, 5.2, and 4.1 times the SQO, respectively. These phenanthrene enrichments co-occur with elevated HCBD concentrations (see below). In sample 7A-S1, a phenanthrene enrichment of 8.7 times the SQO co-occurs with elevated PCB concentrations, but with lesser enrichments of HCBD and dibenz(a,h)anthracene.

Total PCBs. The SQO for PCBs was exceeded throughout much of the central and southeastern part of the underpier side slope area, typically throughout the entire length of the 3-foot cores. The highest concentrations, with enrichment ratios ranging from 5 to 13 times the SQO, were detected across a broad area that included both core sections at locations 3B, 5B, 7A, 7B, 9A, and 11A. Although the PCB enrichments in the central part of the underpier area coincide with similar enrichments in surface sediments (see Figure 5-1), PCB enrichments in the southeastern part of the study area are restricted to the subsurface and are not evident in surface samples. In contrast, PCB concentrations were generally below the SQO in the northwestern part of the underpier area, except in sample IY-C-05-S2. However, moderate PCB enrichment in this sample (3.1 times the SQO) was superseded by higher enrichments of PAHs and HCBD.

Hexachlorobutadiene. The highest enrichments of HCBD were detected in the southeastern part of the underpier area, near the property boundary with Pioneer Chlor Alkali Company and HCC Area 5106. In particular, locations 1A, 3B, and 5B contained maximum HCBD enrichments of 6,500, 9, and 25 times the SQO, respectively, throughout the entire 3-foot length of core. Interpretation of much of the central part of the underpier area is confounded by elevated detection limits between 4 and 14 times the SQO. Detected concentrations between 5 and 8 times the SQO were also scattered about the central and northwestern parts of the underpier area, including samples 9B-S1, 11B-S1, IY-C-01, and IY-C-05, with enrichment ratios of 5.0, 6.5, 7.6, and 4.6, respectively. The spatial relationship between these enrichments and those on the southeastern part of the side slope cannot be discerned because of the elevated detection limits in the intervening areas.

Enrichment Ratios for Total PCBs in Surface Samples

Port of Tacoma Industrial Yard



Notes: 1. Bathymetry from Striplin et al., 1997, and Blue Water Engineering, 1997

2. Enrichment ratios shown for Total PCBs concentrations relative to its SQO of 300 μg/kg.

Sample Location, Number, Type (Depth), and Reference

● IY-B-01	Bank Sample (0 to 10 cm) Port of Tacoma, 1998	□ 7A	Slope Surface Sample (0 to 0.3 Foot) Occidental Chemical, 1998
▲ IY-UB-01	Upper Bank Sample (0 to 10 cm) Port of Tacoma, 1998	⊕ 5135	Subtidal Sediment Sample (HCC, 1994–1996)
■ IY-S-04	Slope Surface Sample 0 (0 to 10 cm) Port of Tacoma, 1998	⊕ HY-04	Subtidal Sediment Sample (HCC, 1994 and NOAA–Trustees, 1994)
○ 10	Bank Sample (0 to 10 cm) Occidental Chemical, 1998	1.2	Enrichment Ratio for Total PCBs
		NA	Not Analyzed

Elevation Contour in Feet (MLLW)

Enrichment Ratio Contour

> 10

> 5

> 3

> 1

0 100 200

Scale in Feet

N

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Figure 5-1

8.7.2.46.4

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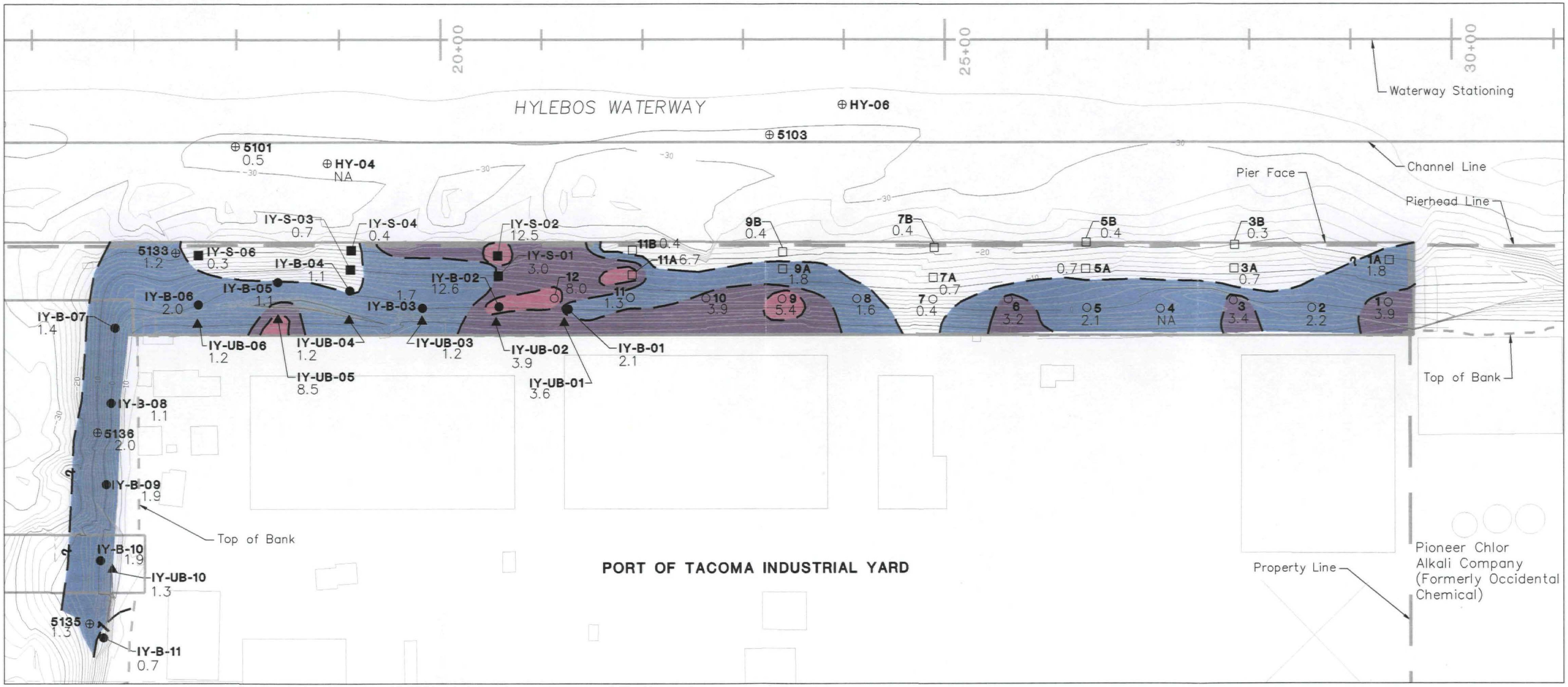
CVD 10/30/98 1=100 COLOR.PC2 xref=colrbase and colrcontour 48580331

Region 10
Superfund Records Center

Enrichment Ratios for Zinc in Surface Samples

Port of Tacoma Industrial Yard



Sample Location, Number, Type (Depth), and Reference

● IY-B-01	Bank Sample (0 to 10 cm) Port of Tacoma, 1998
▲ IY-UB-01	Upper Bank Sample (0 to 10 cm) Port of Tacoma, 1998
■ IY-S-04	Slope Surface Sample 0 (0 to 10 cm) Port of Tacoma, 1998
○ 10	Bank Sample (0 to 10 cm) Occidental Chemical, 1998
□ 7A	Slope Surface Sample (0 to 0.3 Foot) Occidental Chemical, 1998
⊕ 5135	Subtidal Sediment Sample (HCC, 1994–1996)
⊕ HY-04	Subtidal Sediment Sample (HCC, 1994 and NOAA–Trustees, 1994)
1.2	Enrichment Ratio for Zinc
NA	Not Analyzed

Elevation Contour in Feet (MLLW)

Enrichment Ratio Contour

> 5

> 3

> 1

Notes: 1. Bathymetry from Striplin et al., 1997, and Blue Water Engineering, 1997

2. Enrichment ratios shown for Zinc concentrations relative to its SQO of 410 mg/kg.

N

0 100 200

Scale in Feet

HARTCROWSER

J-4858-03 10/98

Figure 5-2

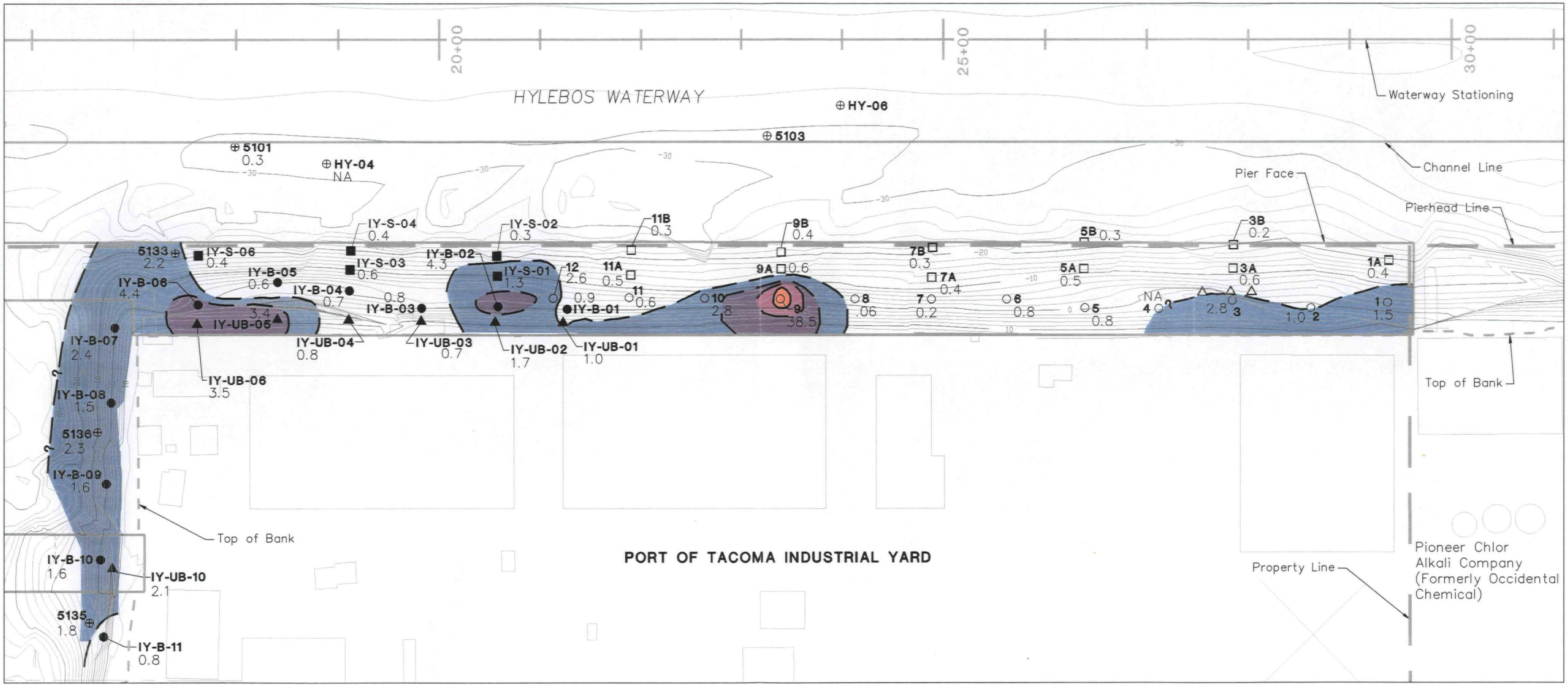
8.7.2.46.4

2

CVD 10/22/98 1=100 COLOR.PC2 xref=colrbase and colrcontour
48580332

Enrichment Ratios for Copper in Surface Samples

Port of Tacoma Industrial Yard



Sample Location, Number, Type (Depth), and Reference

- ● IY-B-01 Bank Sample (0 to 10 cm) Port of Tacoma, 1998
- ▲ IY-UB-01 Upper Bank Sample (0 to 10 cm) Port of Tacoma, 1998
- ■ IY-S-04 Slope Surface Sample 0 (0 to 10 cm) Port of Tacoma, 1998
- ○ 10 Bank Sample (0 to 10 cm) Occidental Chemical, 1998
- □ 7A Slope Surface Sample (0 to 0.3 Foot) Occidental Chemical, 1998
- ⊕ 5135 Subtidal Sediment Sample (HCC, 1994–1996)
- ⊕ HY-04 Subtidal Sediment Sample (HCC, 1994 and NOAA–Trustees, 1994)
- 1.2 Enrichment Ratio for Copper
- NA Not Analyzed

- Elevation Contour in Feet (MLLW)
- Enrichment Ratio Contour
- > 10
- > 5
- > 3
- > 1

Notes: 1. Bathymetry from Striplin et al., 1997, and Blue Water Engineering, 1997

2. Enrichment ratios shown for Copper concentrations relative to its SQO of 390 mg/kg.

N

0 100 200

Scale in Feet

HARTCROWSER

J-4858-03 10/98

Figure 5-3

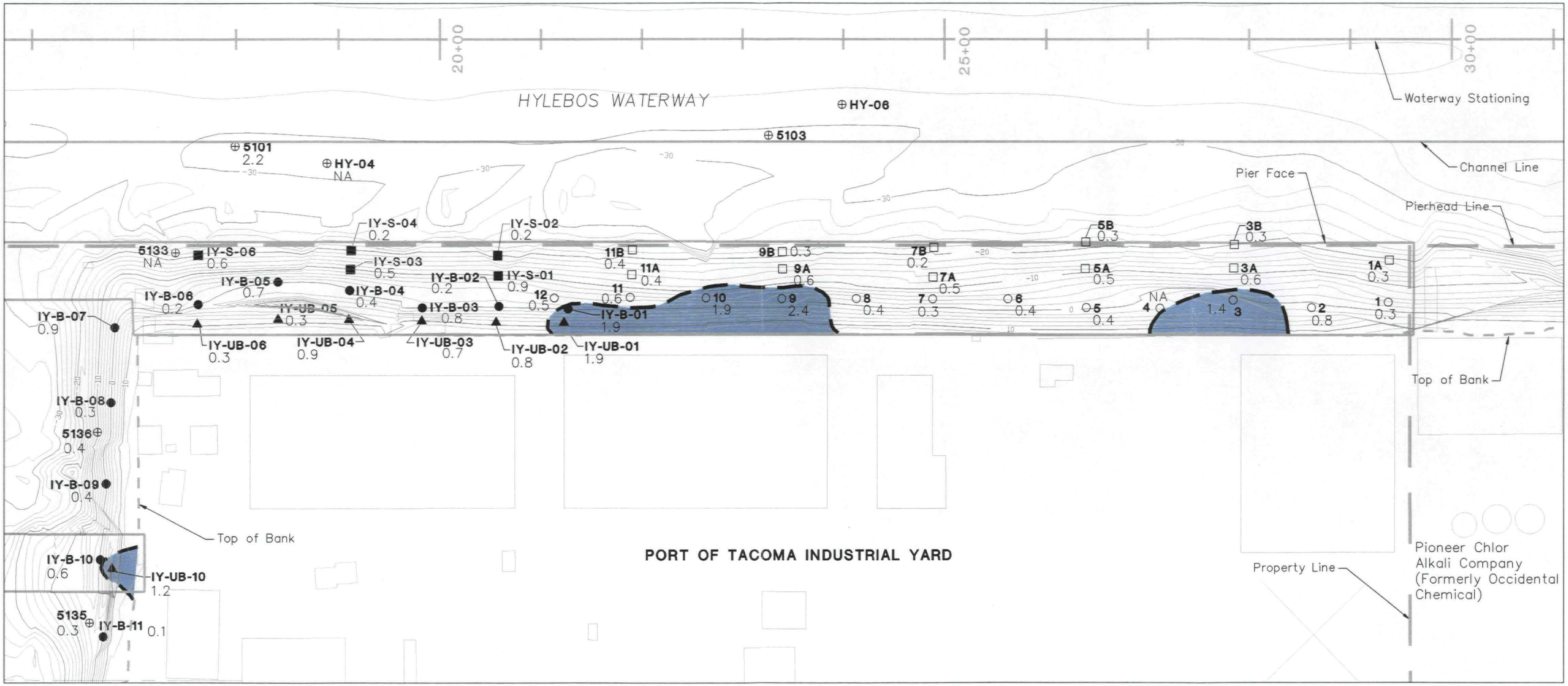
CVD 10/30/98 1=100 color.pc2 xref=colrbase and colrcontour 48580333

8.7.2.46.4

3

Enrichment Ratios for Mercury in Surface Samples

Port of Tacoma Industrial Yard



Notes: 1. Bathymetry from Striplin et al., 1997, and Blue Water Engineering, 1997

2. Enrichment ratios shown for Mercury concentrations relative to its SQO of 0.59 mg/kg.

Sample Location, Number, Type (Depth), and Reference

● IY-B-01	Bank Sample (0 to 10 cm) Port of Tacoma, 1998	□ 7A	Slope Surface Sample (0 to 0.3 Foot) Occidental Chemical, 1998
▲ IY-UB-01	Upper Bank Sample (0 to 10 cm) Port of Tacoma, 1998	⊕ 5135	Subtidal Sediment Sample (HCC, 1994–1996)
■ IY-S-04	Slope Surface Sample 0 (0 to 10 cm) Port of Tacoma, 1998	⊕ HY-04	Subtidal Sediment Sample (HCC, 1994 and NOAA–Trustees, 1994)
○ 10	Bank Sample (0 to 10 cm) Occidental Chemical, 1998	1.2	Enrichment Ratio for Mercury
		NA	Not Analyzed

Elevation Contour in Feet (MLLW)

Enrichment Ratio Contour

> 1

N

0 100 200

Scale in Feet

HARTCROWSER

J-4858-03 10/98

Figure 5-4

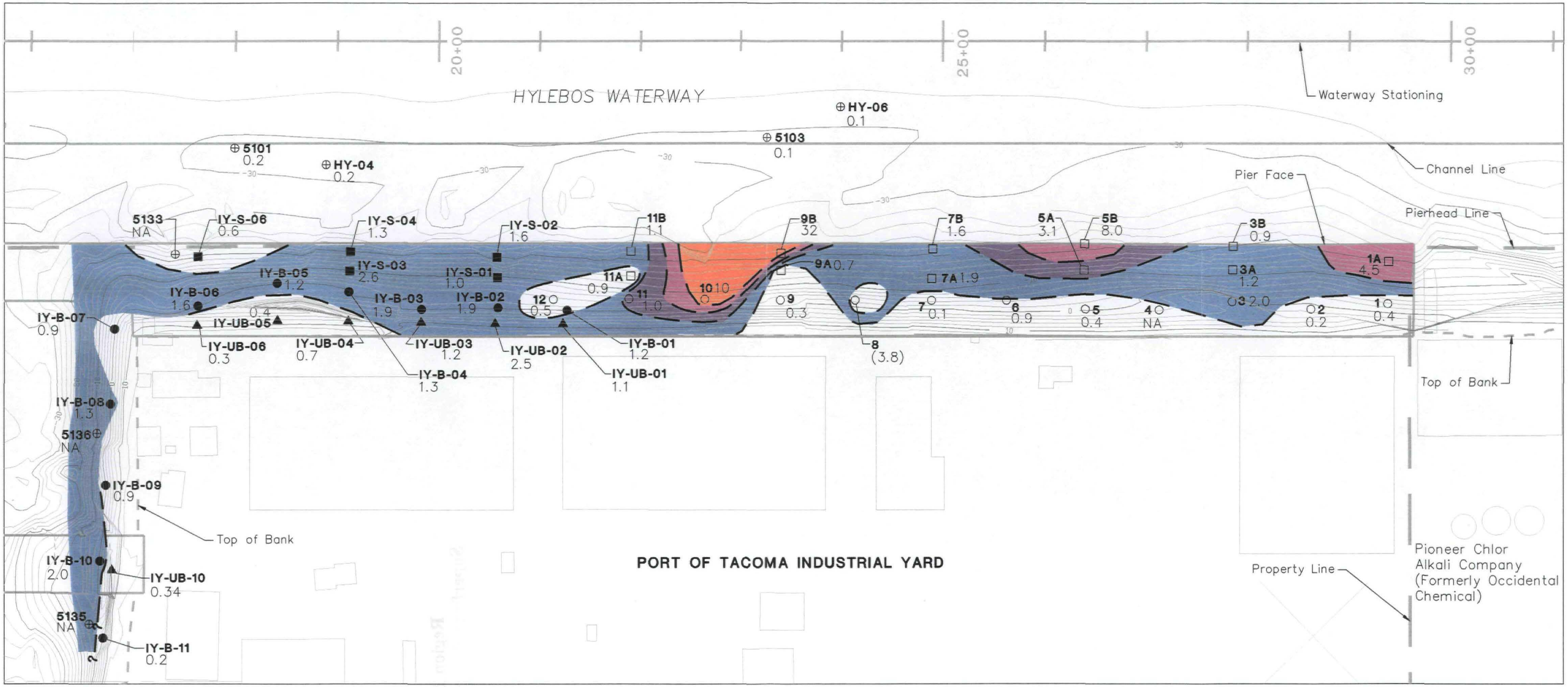
CVD 10/30/98 1=100 COLOR.PC2
4858031 2

8.7.2.46.3

4

Enrichment Ratios for Phenanthrene in Surface Samples

Port of Tacoma Industrial Yard



Notes: 1. Bathymetry from Striplin et al., 1997, and Blue Water Engineering, 1997

2. Enrichment ratios shown for Phenanthrene concentrations relative to its SQO of 1500 μg/kg.

Sample Location, Number, Type (Depth), and Reference

● IY-B-01 Bank Sample (0 to 10 cm) Port of Tacoma, 1998

▲ IY-UB-01 Upper Bank Sample (0 to 10 cm) Port of Tacoma, 1998

■ IY-S-04 Slope Surface Sample 0 (0 to 10 cm) Port of Tacoma, 1998

○ 10 Bank Sample (0 to 10 cm) Occidental Chemical, 1998

□ 7A Slope Surface Sample (0 to 0.3 Foot) Occidental Chemical, 1998

⊕ 5135 Subtidal Sediment Sample (HCC, 1994–1996)

⊕ HY-04 Subtidal Sediment Sample (HCC, 1994 and NOAA–Trustees, 1994)

1.2 Enrichment Ratio for Phenanthrene

NA Not Analyzed

-30 Elevation Contour in Feet (MLLW)

Enrichment Ratio Contour

> 10

> 5

> 3

> 1

N

0 100 200

Scale in Feet

HARTCROWSER

J-4858-03 10/98

Figure 5-5

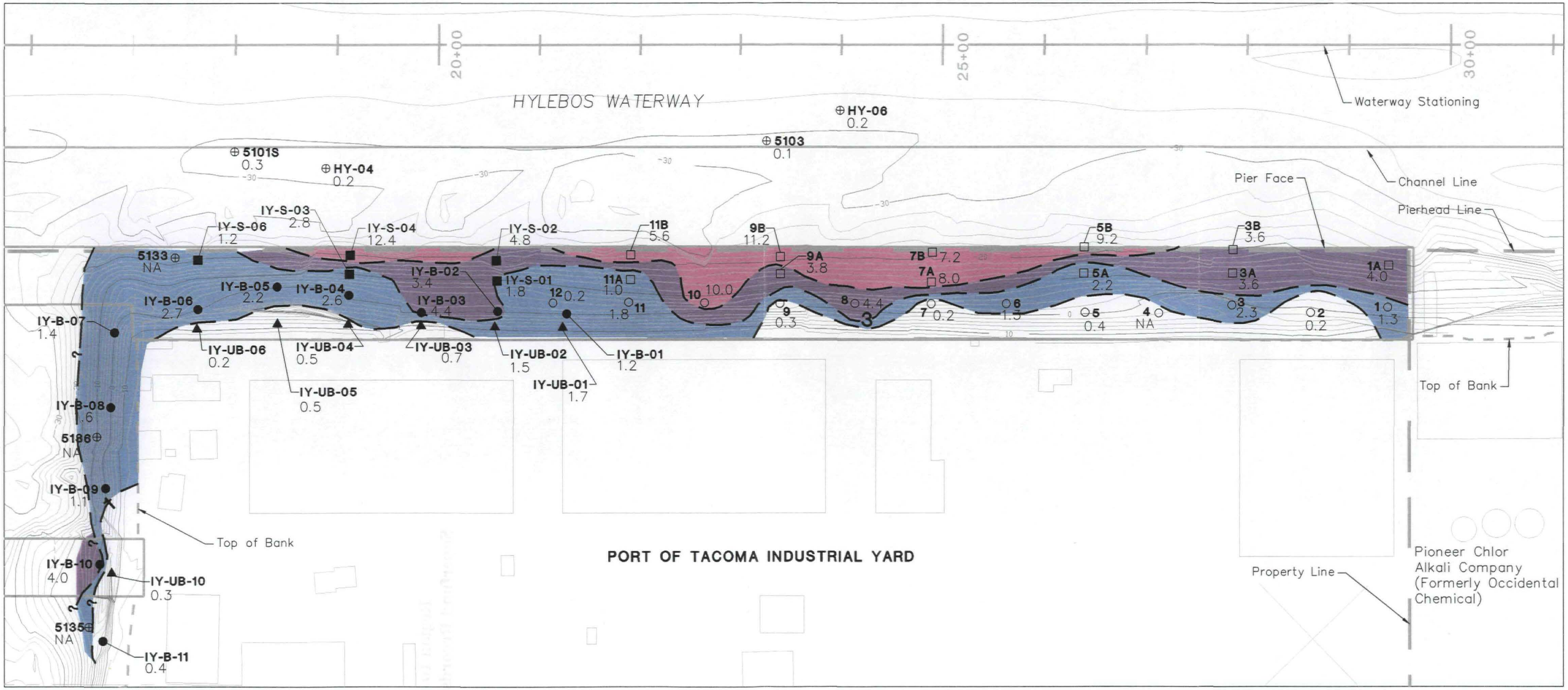
8.7.2.46.3

CVD 10/30/98 1=100 COLOR.PC2 XREF=colrbase and colrcontour 4858039

5

Enrichment Ratios for Fluoranthene in Surface Samples

Port of Tacoma Industrial Yard



Sample Location, Number, Type (Depth), and Reference

- ● IY-B-01 — Bank Sample (0 to 10 cm) Port of Tacoma, 1998
- ▲ IY-UB-01 — Upper Bank Sample (0 to 10 cm) Port of Tacoma, 1998
- ■ IY-S-04 — Slope Surface Sample 0 (0 to 10 cm) Port of Tacoma, 1998
- ○ 10 — Bank Sample (0 to 10 cm) Occidental Chemical, 1998
- □ 7A — Slope Surface Sample (0 to 0.3 Foot) Occidental Chemical, 1998
- ⊕ 5135 — Subtidal Sediment Sample (HCC, 1994–1996)
- ⊕ HY-04 — Subtidal Sediment Sample (HCC, 1994 and NOAA–Trustees, 1994)
- 1.2 — Enrichment Ratio for Fluoranthene
- NA — Not Analyzed

-30 Elevation Contour in Feet (MLLW)

Enrichment Ratio Contour

- > 5
- > 3
- > 1

Notes: 1. Bathymetry from Striplin et al., 1997, and Blue Water Engineering, 1997

2. Enrichment ratios shown for Fluoranthene concentrations relative to its SQO of 2500 μg/kg.

N

0 100 200

Scale in Feet

HARTCROWSER

J-4858-03 10/98

Figure 5-6

8.7.2.46.3

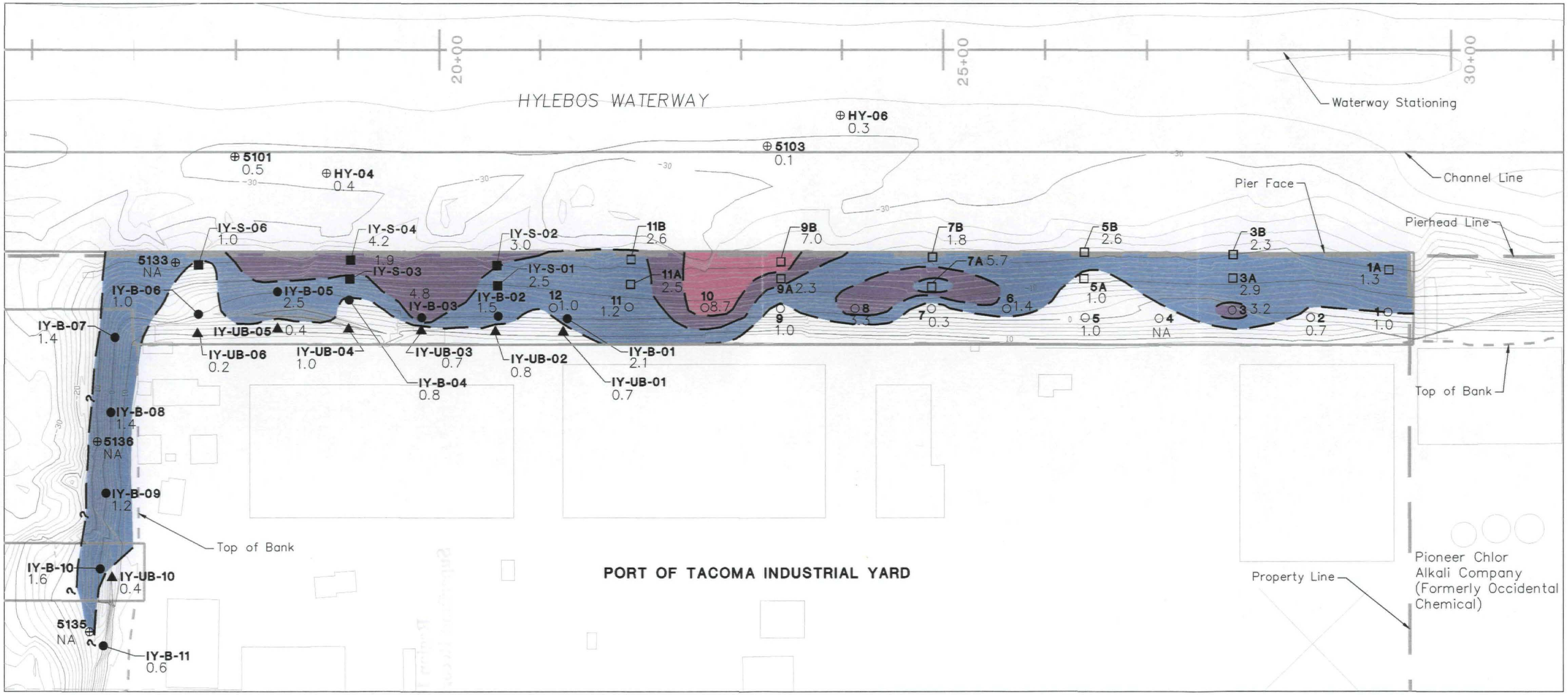
6

CVD 10/30/98 1=100 COLOR.PC2 xref=colrbase and colrcontour
48580334

Region 10
Superfund Records Center

Enrichment Ratios for Dibenz(a,h)anthracene in Surface Samples

Port of Tacoma Industrial Yard



Sample Location, Number, Type (Depth), and Reference

● IY-B-01 Bank Sample (0 to 10 cm) Port of Tacoma, 1998

▲ IY-UB-01 Upper Bank Sample (0 to 10 cm) Port of Tacoma, 1998

■ IY-S-04 Slope Surface Sample 0 (0 to 10 cm) Port of Tacoma, 1998

○ 10 Bank Sample (0 to 10 cm) Occidental Chemical, 1998

□ 7A Slope Surface Sample (0 to 0.3 Foot) Occidental Chemical, 1998

⊕ 5135 Subtidal Sediment Sample (HCC, 1994–1996)

⊕ HY-04 Subtidal Sediment Sample (HCC, 1994 and NOAA–Trustees, 1994)

1.2 Enrichment Ratio for Dibenz(a,h)anthracene

NA Not Analyzed

Elevation Contour in Feet (MLLW)

Enrichment Ratio Contour

> 5

> 3

> 1

Notes: 1. Bathymetry from Striplin et al., 1997, and Blue Water Engineering, 1997

2. Enrichment ratios shown for Dibenz(a,h)anthracene concentrations relative to its SQO of 230 µg/kg.

N

0 100 200

Scale in Feet

HARTCROWSER

J-4858-03 10/98

Figure 5-7

CVD 10/30/98 1=100 COLOR.PC2
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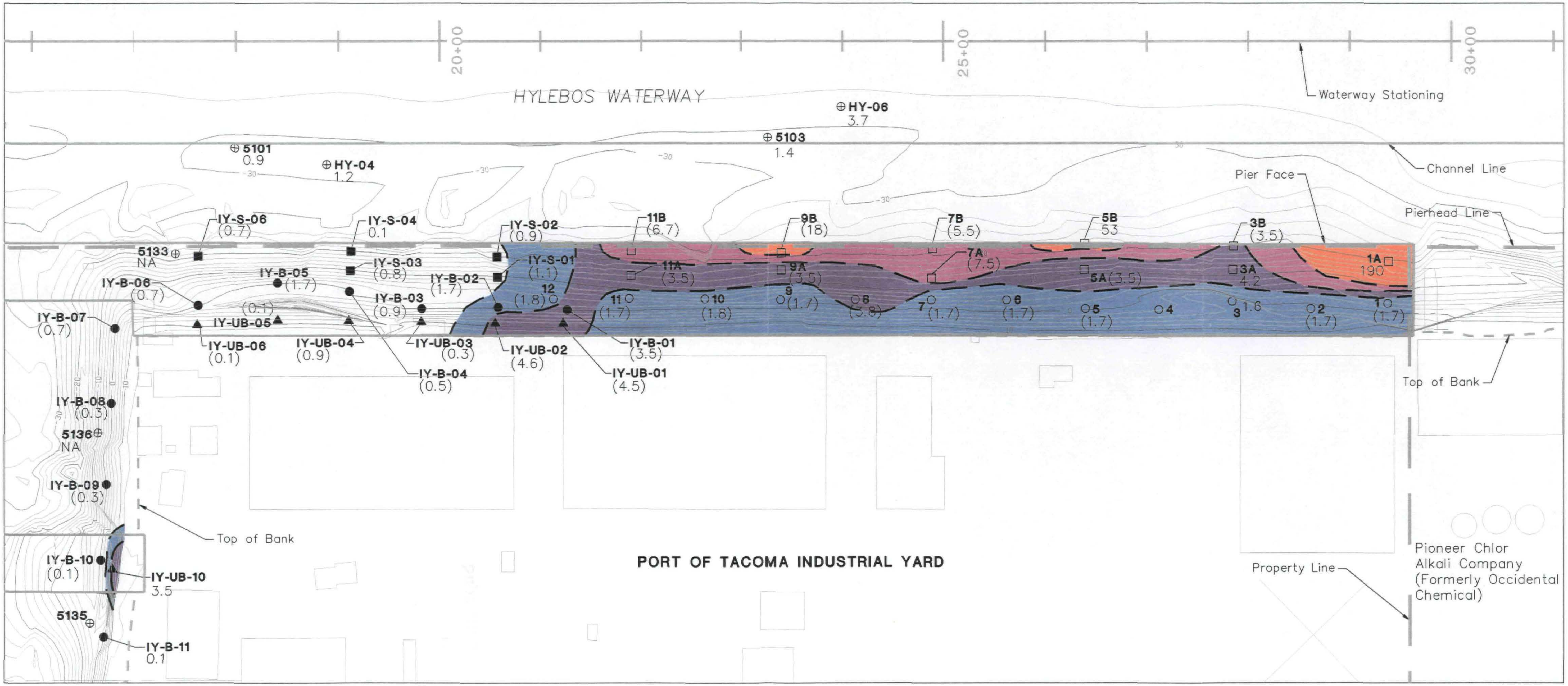
8.7.2.46.3

7

Enrichment Ratios for Hexachlorobutadiene in Surface Samples

Port of Tacoma Industrial Yard



Notes: 1. Bathymetry from Striplin et al., 1997, and Blue Water Engineering, 1997

2. Enrichment ratios shown for HCBD concentrations relative to its SQO of 11 µg/kg.

Sample Location, Number, Type (Depth), and Reference

● IY-B-01	Bank Sample (0 to 10 cm) Port of Tacoma, 1998
▲ IY-UB-01	Upper Bank Sample (0 to 10 cm) Port of Tacoma, 1998
■ IY-S-04	Slope Surface Sample 0 (0 to 10 cm) Port of Tacoma, 1998
○ 10	Bank Sample (0 to 10 cm) Occidental Chemical, 1998
□ 7A	Slope Surface Sample (0 to 0.3 Foot) Occidental Chemical, 1998
⊕ 5135	Subtidal Sediment Sample (HCC, 1994–1996)
⊕ HY-04	Subtidal Sediment Sample (HCC, 1994 and NOAA–Trustees, 1994)
1.2	Enrichment Ratio for HCBD
NA	Not Analyzed

Elevation Contour in Feet (MLLW)

Enrichment Ratio Contour

> 10

> 5

> 3

> 1

N

0 100 200

Scale in Feet

HARTCROWSER

J-4858-03 10/98

Figure 5-8

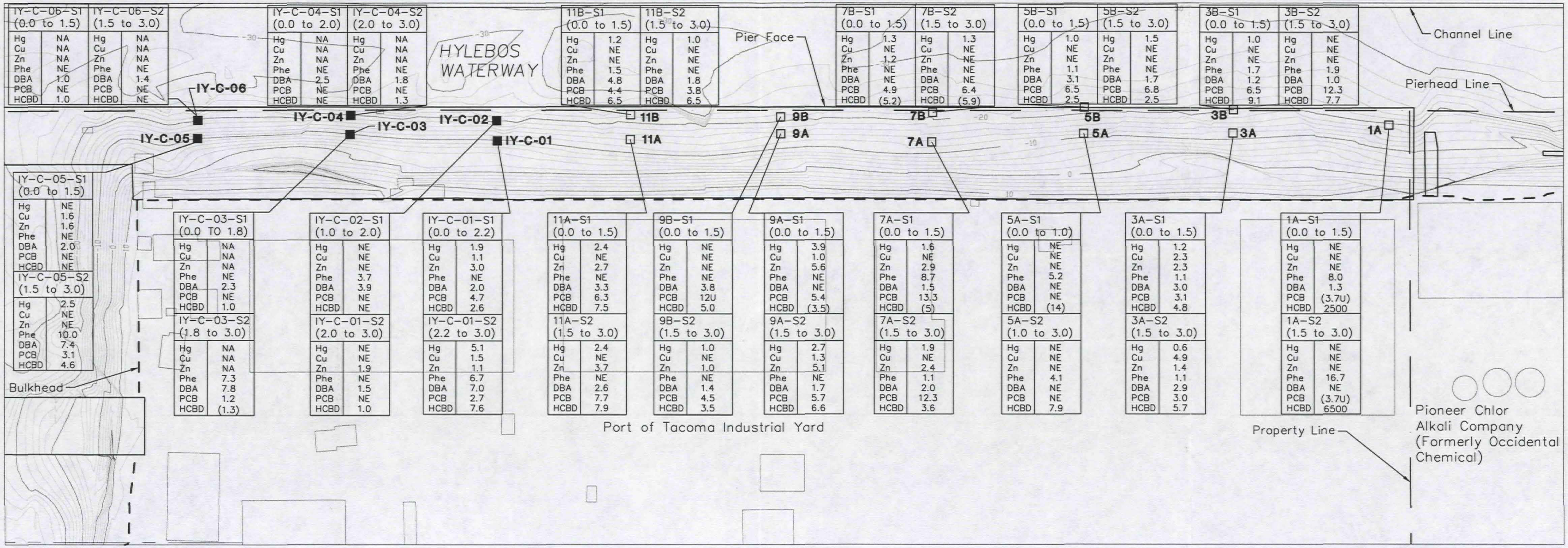
CVD 10/30/98 1=100 COLOR.PC2 XREF=colrbase and colrcontour 48580336

8.7.2.46.3

8

Enrichment Ratios for Key Constituents in Subsurface Samples

Port of Tacoma Industrial Yard



Sample Location, Number, Type (Depth), and Reference

■ **IY-C-04** Subsurface Core Port of Tacoma, 1998

□ **7A** Subsurface Core Occidental Chemical, 1998

-30- Elevation Contour in Feet (MLLW)

IY-C-02-S1 (1.0 to 2.0) — Sample Number (Depth in Feet)

Hg	NE
Cu	NE
Zn	NE
Phe	7.3
DBA	3.9
PCB	NA

Enrichment Ratio

Constituent

Notes: 1. Bathymetry from Striplin et al., 1997, and Blue Water Engineering, 1997

2. Enrichment Ratios (ER) shown for concentrations of key constituents relative to their respective SQOs.

Constituent	SQO
Mercury (Hg)	0.59 mg/kg
Copper (Cu)	390 mg/kg
Zinc (Zn)	410 mg/kg
Phenanthrene (Phe)	1500 ug/kg
Dibenz(a,h)anthracene (DBA)	230 ug/kg
Total PCBs (PCB)	300 ug/kg
Hexachlorobutadiene (HCBD)	11 ug/kg

3. NE = No Exceedence of SQO

4. NA = Not Analyzed

5. Results in ( ) = Enrichment Ratio Based on Undetected Concentration Detection Limit/SQO

N

0 100 200

Scale in Feet

CVD 10/27/98 1=100 woodstk.pc2
48580310

HARTCROWSER

J-4858-03 10/98

Figure 5-9

8.7.2.46.3

9

6.0 SEDIMENT MANAGEMENT AREAS (SMAS)

Sediment Management Areas (SMAs) for the Industrial Yard were delineated based on sampling and analysis completed for this study and concurrent work completed by Oxychem beneath Pier 25. The delineation of SMAs is intended to subdivide the site into areas of similar chemical and physical characteristics which can be addressed using a consistent remedial technology. These SMAs provide the building blocks for the development of a comprehensive, site-wide remedial alternative, which will be the subject of a future feasibility study.

Preliminary estimates of sediment volumes contained in each SMA are also provided in this section. However, the depth of SQO exceedence was not constrained in the subsurface explorations from the Industrial Yard, and virtually all cores contained SQO exceedences extending to at least 3 feet in depth, across the entire coring interval. For purposes of calculating SMA volumes, it was assumed that the depth of contamination extends from mudline to a depth of 4 feet (i.e., depth of penetration plus 1 foot). Additional deeper explorations should be performed during remedial design to further refine these estimates of depth of contamination and SMA volumes. Furthermore, no overdredge allowances or bulking factors have been applied to these *in situ* volume estimates.

No SMA boundaries transgress the 0 foot MLLW contour because of the change in material type at this elevation—riprap above and soft sediment below—and associated differences in the remedial technologies that must be applied to these areas. The SMAs identified for the Industrial Yard are delineated on Figure 6-1. A summary of preliminary volume estimates for each SMA is presented in Table 6-1. A description of each SMA is presented below.

6.1 Side Slope Areas

SMA-1A

This sediment management area encompasses peripheral areas of the site below 0 feet MLLW with low-level enrichments between 1 and 3 times the SQO. Practically the entire area beneath Pier 25, and the entire bank on the Commencement Bay side of the former shipyard, contain an SQO exceedence for at least one constituent. Low level exceedences on the side slope areas are typically dominated by PAHs, whereas low level exceedences on the bank areas, both underpier and Commencement Bay side banks, are typically dominated by copper and zinc. These low level enrichments may be addressed using less aggressive remedial technologies. Higher level enrichments which may require more aggressive remedial technologies are separated into unique SMAs, as discussed below. The estimated volume of impacted sediments within this SMA is approximately 2,000 cubic yards (CY) in the underpier area, and another 2,000 CY along the Commencement Bay side bank, for a total volume of 4,000 CY. However, the seaward extent of copper, zinc, and PAH enrichments on the side slope facing Commencement Bay is not well-delineated.

SMA-2A

This sediment management area consists of an apron of sediments below elevation 0 feet MLLW, adjacent to the northwestern debris pile (SMA-3; see below). This SMA contains enrichments of PCBs between 4 and 24 times the SQO, and also enrichments of copper as high as 4 times the SQO. Assuming the depth of contamination extends to a depth of 4 feet, the estimated volume of impacted sediments within this unit is 520 CY.

SMA-4A

This sediment management area covers a broad portion of the central underpier area. It is primarily characterized by high concentrations of PCBs between 3 and 27 times the SQO in both surface and subsurface sediments, more typically between 5 and 10 times the SQO. Elevated concentrations of zinc (up to 13 times the SQO), copper (up to 39 times the SQO), and PAHs (up to 10 times the SQO) are also present. PCB enrichments also extend up the bank onto riprap areas in associated SMA-4B (see below). Assuming the depth of contamination extends to a depth of 4 feet, the estimated volume of impacted sediments within this unit is 2,440 CY.

SMA-7

This sediment management area is primarily characterized by elevated concentrations of hexachlorobutadiene, peaking at 190 times the SQO in surface sediments along the southeastern corner of the underpier area (Oxychem sample 1A), and 6,500 times the SQO in subsurface sediments from the same location. This area also grades toward the northwest into PAH enrichments on the lower slope, peaking at fluoranthene concentrations 12 times the SQO (IY-S-04) and dibenz(a,h)anthracene concentrations 7 times the SQO (Oxychem sample 9B) in surface sediments, and fluoranthene concentrations 5 times the SQO (IY-C-03-S2) and dibenz(a,h)anthracene concentrations 8 times the SQO (also in IY-C-03-S2) in subsurface sediments. The extreme enrichments of HCBD in surface and subsurface sediments along the southeastern corner of the site are clearly related to Area 5106, and should therefore be addressed by the HCC. These HCBD enrichments are so severe that more aggressive remedial technologies may need to be employed. These enrichments should be split out as a separate SMA, but the extent of the HCBD hot spot cannot presently be discerned because of elevated HCBD detection limits in the Oxychem investigation. The estimated volume of impacted sediments within this SMA is 6,040 CY.

6.2 Upper Bank Areas

SMA-1B

This sediment management area encompasses peripheral areas of the bank above elevation 0 foot MLLW with low level enrichments between 1 and 3 times the SQO. Every upper bank sample contained an SQO exceedence of at least one constituent. Low level exceedences on the upper banks are typically dominated by copper and zinc. These low level enrichments may be addressed using less aggressive remedial technologies. Higher level enrichments on the bank which may require more aggressive remedial technologies are separated into unique SMAs, as discussed below. These gravelly and shallow (less than 1-foot-thick) sediments are found in isolated deposits in the interstices of the riprap; as a result, volumes cannot be calculated, and removal is probably not practicable.

SMA-2B

This sediment management area is located on the bank above the northwestern debris pile (SMA-3, see below). SMA-2B contains copper enrichments as high as 3.5 times the SQO (IY-UB-06), and zinc enrichments as high as 8.5 times the SQO (IY-UB-05). The copper and zinc signature is consistent with field observations of black grit along the shoreline, probably sandblast residues. These gravelly and shallow (less than 1-foot-thick) sediments are found in isolated deposits in the interstices of the riprap; as a result, volumes cannot be calculated, and removal is probably not practicable.

SMA-4B

This sediment management area is characterized by extreme concentrations of PCBs in two upper bank samples. Samples IY-UB-01 and IY-UB-02 contained PCB enrichments equal to or greater than 100 times the SQO. This hot spot may be the source of elevated PCB concentrations in adjacent sediments below 0 feet MLLW. The southeastern extent of the hot spot is not defined because upper bank samples were not collected in the Oxychem investigation. These gravelly and shallow (less than 1-foot-thick) sediments are found in isolated deposits in the interstices of the riprap; as a result, volumes cannot be calculated, and removal is probably not practicable.

6.3 Debris Areas

SMA-3 and SMA-5

Two anthropogenic debris piles, designated SMA-3 and SMA-5, are present on the Hylebos Waterway side of the property. These piles are comprised of fused metallic debris that may have been historically disposed of in the waterway through trap doors on the pier. The debris piles are considered source material and may be a potential source of on-going contamination to the adjacent sediments. The smaller northwestern pile (SMA-3) is estimated to be about 50 by 20 by 6 feet tall, and the larger southeastern pile (SMA-5) is estimated to be about 100 by 25 by 8 to 10 feet tall. Estimated volumes for the debris contained within SMA-3 and SMA-5 are 222 and 926 CY, respectively.

SMA-6

A third area of debris covers much of the upper bank beneath Pier 24 on the Commencement Bay side of the peninsula. The debris consists of fused metal scraps, very similar to the debris piles in SMA-3 and SMA-5. The debris within SMA-6 conforms to the slope and the thickness of the deposit could not be easily estimated. As a result, no volume estimate could be calculated.

Table 6-1 Preliminary Industrial Yard *In Situ* Sediment Volumes

Sediment Management Area	Approximate Area in Square Feet	Estimated Depth of Contamination in Feet[1]	Estimated Volume in Cubic Yards[2]	Nature of Contamination
SMA-1A	27,000	4	4,000	PAHs, Copper, Zinc, HCBD
SMA-1B	25,000	NA	NA	PAHs, Copper, Zinc, HCBD
SMA-2A	3,500	4	520	PCBs, Copper, Zinc, HCBD
SMA-2B	3,500	NA	NA	Copper, Zinc
SMA-3	1,000	6	220	Source Material
SMA-4A	16,500	4	2,440	PCBs, PAHs, Copper, Zinc
SMA-4B	9,500	NA	NA	PCBs
SMA-5	2,500	10	930	Source Material
SMA-6	1,200	NA	NA	Source Material
SMA-7	40,800	4	6,040	HCBD, PAHs, Zinc

Notes:
NA- Not Applicable due to non-continuous sediment deposits in riprap.

1 Depth of contamination in SMA-1A, SMA-2A, SMA-4A, and SMA-7 has not been constrained; volumes may represent minimum estimates.

2 No overdredge allowances or bulking factors have been applied.

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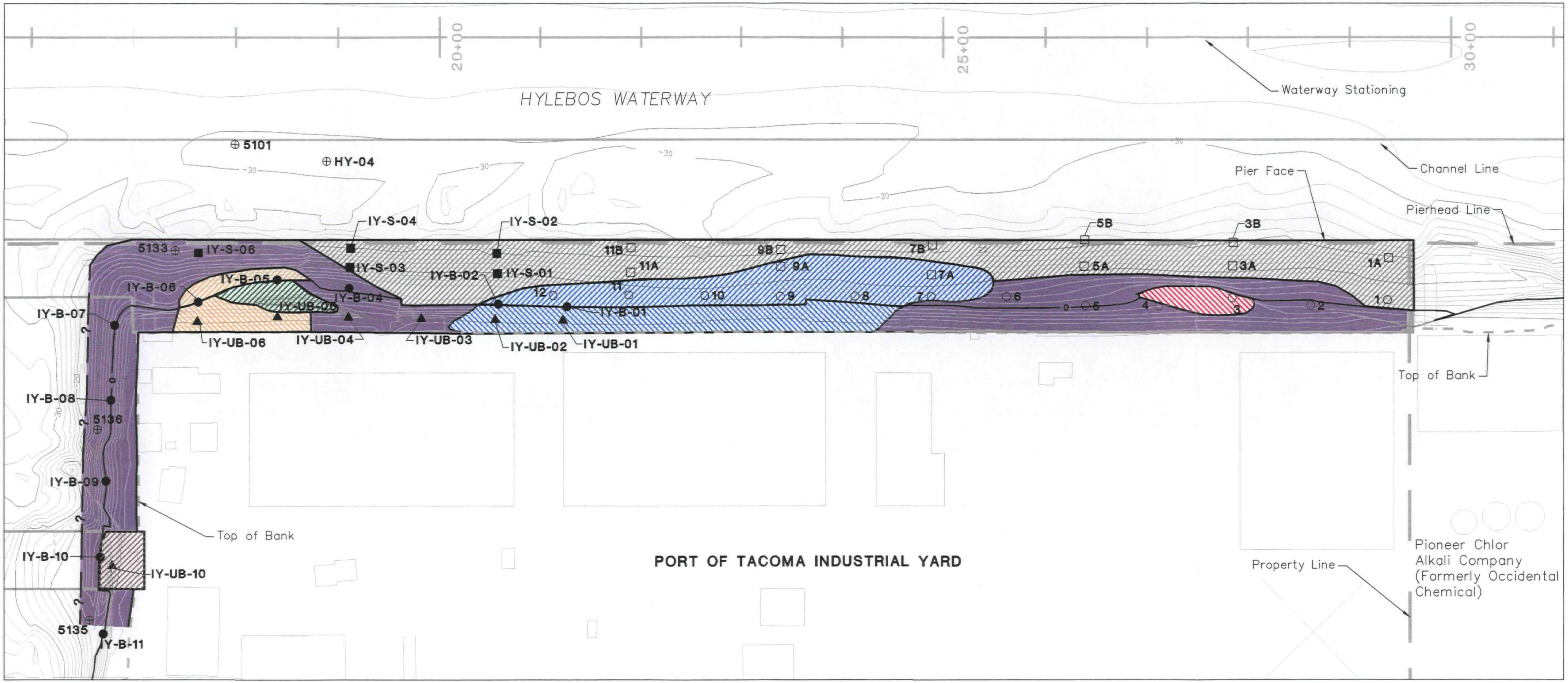
Preliminary Sediment Management Areas (SMAs)

Port of Tacoma Industrial Yard



Sample Location, Number, Type (Depth), and Reference

● IY-B-01	Bank Sample (0 to 10 cm) Port of Tacoma, 1998	
▲ IY-UB-01	Upper Bank Sample (0 to 10 cm) Port of Tacoma, 1998	
■ IY-S-04	Slope Surface Sample 0 (0 to 10 cm) Port of Tacoma, 1998	
○ 10	Bank Sample (0 to 10 cm) Occidental Chemical, 1998	
□ 7A	Slope Surface Sample (0 to 0.3 Foot) Occidental Chemical, 1998	
⊕ 5135	Subtidal Sediment Sample (HCC, 1994–1996)	
⊕ HY-04	Subtidal Sediment Sample (HCC, 1994 and NOAA–Trustees, 1994)	
1.2	Enrichment Ratio for Total PCBs	
NA	Not Analyzed	
-30	Elevation Contour in Feet (MLLW)	

SMA–1

SMA–2A

SMA–2B

SMA–3 (Debris Pile)

SMA–4A

SMA–4B

SMA–5 (Debris Pile)

SMA–6 (Debris Pile)

SMA–7

Notes: 1. Bathymetry from Striplin et al., 1997, and Blue Water Engineering, 1997

N

0 100 200

Scale in Feet

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Figure 6-1

Insert after 6-5

8.7.2.46.4

PR Design Study v.1

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APPENDIX A
FIELD ACTIVITIES AND METHODS

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FIELD ACTIVITIES AND METHODS

This appendix summarizes the field activities conducted between November 1997 and January 1998 as part of the Pre-Remedial Design Study of the Port of Tacoma Industrial Yard (Industrial Yard). The Industrial Yard Pre-Remedial Design Study field activities were performed in general accordance with the agency reviewed Pre-Remedial Design Study Project Plans (Port of Tacoma, 1997) developed for this project. A brief summary of the specific field activities and sample collection methods is presented below along with a discussion of modifications to the project plans.

A.1 Summary of Field Activities

Port of Tacoma Industrial Yard Pre-Remedial Design Study activities include:

- Diver visual and video tape site reconnaissance survey;
- Diver sampling of side slope surface and subsurface sediments; and
- Diver sampling of bank area surface sediments.

The site reconnaissance of the Industrial Yard was conducted on November 20 and 21, 1997. Surface and subsurface sediment quality sampling to characterize the bank and side slope sediments was performed between January 19 and 22, 1998. The field activities were performed by Hart Crowser and subcontracted personnel on behalf of the Port of Tacoma. A chronology of field sampling activities is presented in Table A-1. Confirmed surface and subsurface sampling locations are depicted on Figure A-1. Table A-2 presents a summary of confirmed sampling locations (i.e., coordinates, mudline elevations).

A.2 Surface Sediment Sampling

Surface sediment sampling was accomplished using diver collection methods and hand sampling methods during low tide conditions. The surface sediment samples collected from both the side slope and bank areas were submitted for chemical and conventional analysis. Select samples were submitted for physical testing. At each sampling location collocated with a subsurface sample, surface samples were collected first to ensure that the sediments were relatively undisturbed by the other sampling activities. The diving operations were performed from the vessel *Shelly Marie* which was anchored near the sampling location during diving activities. The *Shelly Marie* is owned and operated by Kushner Marine of Anacortes, Washington.

Section A2.0 of the Pre-Remedial Design Project Plans presents detailed descriptions of the surface sediment sampling methods, sample handling and decontamination procedures, and sample custody protocols. The sediment sampling and handling were performed in general accordance with the Sampling and Analysis Plan of the Pre-Remedial Design Project Plans. Sample locations were selected to be representative of the surface sediment condition and to provide adequate spatial coverage of the site and fill any obvious data in the existing data, and confirm previous sampling results.

In total, 23 surface samples (not including field duplicates), representative of the surface sediment condition were submitted to Analytical Resources Incorporated of Seattle, Washington and Columbia Analytical Services of Kelso, Washington for analysis of sediment conventionals, and chemical compounds with established SQOs. Four samples, representative of the Industrial Yard surface sediment grain size types were submitted to the Hart Crowser geotechnical laboratory for grain size testing. Field descriptions of the surface sediment samples are presented in Table A-3.

A.2.1 Side Slope Areas

Surface sediment samples were collected at six side slope sampling locations from target elevations near -10 and -20 feet MLLW. Sediment samples, representative of the upper 10 centimeters of sediment, were collected by diver using 3-inch-diameter stainless steel cylinders. Multiple cylinders were used at each location to collect the necessary sediment volume from each location.

The diver was guided to each sampling location using pre-surveyed markers located on the shore line and identifiable objects on the AUTOCAD base map of the site. Upon retrieval and acceptance, each sediment sample was logged and processed in the field. Sample information recorded at each location included: mudline elevation, date, time, recovery depth, a visual description of the sediment, and any other relevant sampling information. Sampling equipment was decontaminated prior to use at each location. After filling, sample containers were placed in coolers for transfer to the analytical laboratories.

A.2.2 Bank Areas

Surface sediment samples were collected at eleven bank area locations near the target elevation of 0 feet MLLW and at seven upper bank locations near target elevation 6 feet MLLW. The bank area samples were collected by hand during low tide conditions. Samples were collected using decontaminated stainless steel implements. Multiple scoops were collected at each location to ensure the necessary sediment volume was sampled at each location.

Upon retrieval and acceptance, surface sediment samples were logged and processed in the field as described in A.2.1 above.

A.2.3 Surface Sediment QA/QC Samples

Two homogenized field duplicate samples, IY-S-80 and IY–B-80, were collected from sampling locations IY-S-03 and IY-B-04, respectively. The duplicate samples were collected into separate jars from the same mixing bowl at each location to assess analytical variability. Duplicate samples were subjected to the same chemical analyses as the field samples.

One rinseate blank was collected during the surface sediment sampling activities to assess the effectiveness of the field decontamination procedures. The rinseate blank consisted of deionized water collected after exposure to decontaminated sampling and processing equipment. The surface sediment rinseate blank was labeled IY-B-100. The rinseate blank sample was analyzed for the same chemical parameters as were the sediment samples.

A.2.4 Modifications to the Surface Sediment Sampling Plans

Significant modifications to the Pre-Remedial Design Sampling and Analysis Plans included the following:

- Proposed upper bank surface samples IY-UB-07, IY-UB-08, IY-UB-09, and IY-UB-11 were not collected because sediment was not identified in the vicinity of the proposed sampling locations.

A.3 Subsurface Sediment Sampling

Subsurface sediment sampling (up to 3 feet in depth) was conducted to obtain site representative sediment quality data. Sampling was accomplished using different methods of diver hand coring, each best adapted to the different conditions encountered at the site. These techniques included use of a 4-foot-long stainless steel Hart Sampler or a 4-foot-long, 4-inch-diameter hand core tube. Diving operations were conducted from the vessel *Shelly Marie* which was anchored near the sampling location during diving activities. At sampling locations with collocated surface samples, subsurface samples were collected after retrieval of the surface sample.

Section A2.0 of the Pre-Remedial Design Project Plans presents detailed descriptions of the subsurface sediment sampling methods, sample handling and decontamination procedures, and sample custody protocols. The sediment sampling and handling were performed in general accordance with the Sampling and Analysis Plan of the Pre-Remedial Design Project Plans. Sample locations were selected to be representative of the surface sediment condition and to provide adequate spatial coverage of the site and fill any obvious data gaps in the existing data, and confirm previous sample analytical results.

Subsurface sediment samples collected from the side slope of the Waterway side of the Industrial Yard were submitted for chemical and conventional analysis, and physical testing. Subsurface samples obtained from the side slope area were frozen and archived at the analytical laboratory. In total, 12 subsurface sediment intervals were collected from the bank and side slope areas of the Industrial Yard. All twelve subsurface samples were analyzed by Analytical Resources Incorporated of Seattle, Washington and Columbia Analytical Services of Kelso, Washington for sediment conventionals and chemical compounds that have an established SQO. Four samples, representative of the Industrial Yard subsurface sediment grain size types, were submitted to the Hart Crowser geotechnical laboratory for grain size testing. Sediment core logs, presenting descriptions of the subsurface surface sediment samples are presented on Figures A-3 through A-8. A key to the sediment core logs is presented on Figure A-2.

A.3.1 Side Slope Areas

Subsurface sediment samples were collected at ten side slope sampling locations from target elevations near -10 and -20 feet MLLW. The diver was guided to each sampling location using pre-surveyed markers located on the pier face and measuring the distance toward the bulkhead from the pier face. Upon retrieval and acceptance, each sediment sample was logged and processed in the field. Sample information recorded at each location included: mudline elevation, date, time, recovery depth, a visual description of the sediment, and any other relevant information. Subsamples, representative of the upper core interval (S-1) and lower interval (S-2) were collected from each core sample. Subsample intervals were determined from the observed sediment lithology. In core samples were lithology was not apparent, the subsample interval was determined to be approximately half the core depth. Sampling equipment was decontaminated prior to use at each location. After filling, sample containers were placed in coolers for transfer to the analytical laboratories.

A.3.2 Subsurface Sediment QA/QC Samples

No subsurface duplicate samples were collected or analyzed. Results of the concurrently analyzed surface QA/QC samples were used to assess the analytical variability.

One rinseate blank was collected during the subsurface sediment sampling activities to assess the effectiveness of the field decontamination procedures. The rinseate blank consisted of deionized water collected after exposure to decontaminated sampling and processing equipment. The subsurface sediment rinseate blank was labeled IY-C-100. The rinseate blank sample was analyzed for the same chemical parameters as were the sediment samples.

A.3.3 Modifications to the Subsurface Sediment Sampling Plans

No modifications to the Pre-Remedial Design Sampling and Analysis Plans were made during the sediment coring activities.

A.4 Field Equipment Decontamination

Decontamination was conducted on the sampling equipment which may have contacted sample media as outlined in Section A2.5 of the Sampling and Analysis Plan.

No modifications to the approved project plans were noted.

A.5 Location Control and Documentation

Sampling location control was performed in general accordance with Section A.2.6 of the Sampling and Analysis Plan. Elevations in this study are referenced to Mean Lower Low Water (MLLW). Horizontal locations are referenced to Washington State Plane coordinates (SPC) NAD 83 North Zone datum. Confirmed sampling location coordinates for each sample location are presented in Table A-2.

Sample locations were located by horizontal triangulation and measurement from control points identifiable on the project base map. Actual sample locations were located within 10 feet of the proposed locations unless otherwise noted. Sampling locations were later translated to SPCs from the AUTOCAD base map.

Predictive tide tables were used for local elevation reference comparison during field activities. Throughout the duration of the field work, the tidal predictions were found to be comparable to the actual measurements as posted on the NOAA internet site.

A.5.1 Modifications to the Location Control Plan

No modifications to the Sampling and Analysis Plan for location control were noted.

A.6 Sediment Sample Handling

Sediment sample handling (collecting, packaging, transporting, and documenting) was performed in general accordance with Section A2.8 of the Sampling and Analysis Plan. During sampling activities, the field representative in the "support zone" labeled each jar with the sample identification information, filled and signed the custody forms, and checked each sample set before transport to the laboratory. The field person working in the "hot zone" composited and mixed the sediment samples, filled the sample jars with sediment, and placed the jars into cooled ice chests until transport to the specified laboratory.

Samples were transported to Analytical Resources Incorporated, Columbia Analytical Services, and the Hart Crowser Geotechnical Testing Laboratory as appropriate every one or two days following proper chain of custody procedures as outlined in Section A2.10 of the Sampling and Analysis Plan.

No modifications to the approved project plans were noted.

A.7 Site Reconnaissance Survey

A visual reconnaissance survey along transects extending from toe of side slope (approximately elevation -30 feet MLLW) to the low-tide mark (elevation 0 feet MLLW) was performed on November 20 and 21, 1997. The diver survey was conducted at the beginning of the field investigation to document the *in situ* sediment condition. Results of the diver reconnaissance survey were also used to help identify appropriate subtidal sampling locations. Swim transects were located adequate under pier access was available. Vessel berthing activity during the survey period restricted access to several proposed transect locations. Confirmed transect locations (IY-T-01 through IY-T-09) are shown on Figure A-1.

Along each transect, the diver documented the site condition using both a video camera and transmitting visual descriptions via intercom to the survey crew on board the survey vessel. Specifically, the diver identified any observable debris, potential dredging hazards or impediments, anthropogenic material, and submerged structures at the site. In addition, the diver probed the seafloor with a calibrated rod to estimate the depth of sediment. Recorded observations and sediment probe depths are presented on Figure 3-1.

A.8 Health and Safety Plan Assessment

This section presents an assessment of the Health and Safety Plan (HSP) for the Port of Tacoma Industrial Yard. The purpose of this assessment is to evaluate the adequacy of this plan for ensuring protection of personnel. For this evaluation, monitoring requirements, personal protective equipment (PPE), potential contaminant exposure, and physical hazards were assessed relative to the field sampling tasks performed. Actual conditions encountered are discussed in relation to anticipated hazards. References to audits, accidents, exposures, or exceedence of monitoring levels are also included as applicable.

Field sampling tasks included: site reconnaissance surveys, sample collection, field processing, and transport of sediment samples.

Site Reconnaissance Survey. Limited exposure potential was observed during survey activities. Divers performing the survey were wearing protective outer garments and chemical-resistant gloves. Upon completion of a transect swim, the diver and any equipment used were rinsed thoroughly.

Sample Collection. Limited exposure potential was observed during sediment sampling activities. Personnel handling the sediments were wearing modified Level D protection with protective outer garments and chemical-resistant gloves. Field activities were monitored for hydrogen sulfide (H_2S) exposure by personal H_2S-sensitive badges. Based on field monitoring results, there is no evidence of exposure during field activities. Upon completion of sample collection at each location, the diver and any equipment used were rinsed thoroughly.

Personnel on board the sampling vessel were required to wear personal flotation devices. Personnel followed decontamination procedures before moving from the exclusion zone, returning to the shore after intertidal sampling by foot, and before leaving the vessel.

Sample Processing. Field processing of sediments required direct handling of the sediments. Possible skin contact and ingestion of sediments were kept to a minimum by wearing safety protection which included chemical-resistant gloves, tyvek suits, hard hats, safety glasses, and chemical-resistant rubberized boots. Inhalation routes of exposure for H_2S were minimized by working in well ventilated areas and wearing H_2S badges. Slight H_2S odors were often present in the van Veen grabs samples but the H_2S badges never changed color indicating that hydrogen sulfide never exceeded the PEL-TWA of 10 ppm.

Field Transport. Proper storing and packaging procedures for sample containers were followed to reduce exposure during field transport of samples. N-dex gloves were worn while handling sample jars. No other protective measures to prevent exposure were necessary.

Physical Testing. Physical testing included grain size analysis. The testing of site sediments at the Hart Crowser Soils Laboratory followed the same Health and Safety laboratory procedures as indicated in sample logging and processing. Contaminated material was handling in a restricted area of the lab specifically for hazardous materials, and a vacuum hood was used for sediments with heavy odors. No exposures from site sediments were noted.

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Table A-1 - Chronology of Industrial Yard Pre-Remedial Design Study Field Activities

Date	Field Activity	Sampling Location
November 20 - 21, 199	Site Reconnaissance Survey	IY-T-1 through IY-T-9
January 19 - 22, 1998	Sediment Sampling	IY-S-01 through IY-S-04 and IY-S-06 IYC-01 through IY-C-06 IY-B-01 through IY-B-11 IY-UB-01 through IY-UB-06 IY-UB-10

485803\TableA1.xls

Table A-2 - Confirmed Sampling Location Coordinates

Location Identification	Northing[1]	Easting[1]	Mudline Elevation in Feet MLLW
Side Slope Area			
IY-S-01/IY-C-01	1526665.8	716814.3	-10
IY-S-02/IY-C-02	1526679.2	716828.9	-20
IY-S-03/IY-C-03	1526565.4	716920.3	-10
IY-S-04/IY-C-04	1526578.9	716933.5	-20
IY-C-05	1526455.7	717021.1	-10
IY-S-06/IY-C-06	1526468.4	717033.7	-20
Bank Area			
IY-B-01	1526693.0	716742.8	0
IY-B-02	1526645.4	716792.4	0
IY-B-03	1526590.1	716844.0	0
IY-B-04	1526550.5	716906.0	0
IY-B-05	1526505.7	716961.0	0
IY-B-06	1526434.7	716999.1	0
IY-B-07	1526360.4	717039.5	-3.4
IY-B-08	1526306.5	716989.3	-3.5
IY-B-09	1526247.8	716935.5	-6.8
IY-B-10	1526191.9	716886.0	0
IY-B-11	1526141.4	716829.7	0
IY-UB-01	1526680.9	716736.1	6
IY-UB-02	1526632.6	716783.2	6
IY-UB-03	1526580.8	716835.0	6
IY-UB-04	1526529.9	716885.8	6
IY-UB-05	1526480.5	716934.7	6
IY-UB-06	1526420.6	716985.9	6
IY-UB-10	1526194.1	716871.6	6

Notes:
1. Washington State Plane Coordinates (NAD 83).

485803\TableA2.xls

Table A-3 - Surface Sediment Sample Field Observations

Sample Location	Sample Date	Sample Time	Sediment Description
Upper Bank			
IY-UB-01	1/22/98	16:20	Medium dense, rusty brown sandy GRAVEL with abundant metal debris.
IY-UB-02	1/22/98	16:30	Medium dense, rusty brown sandy GRAVEL with abundant metal debris.
IY-UB-03	1/22/98	16:45	Medium dense, rusty brown sandy GRAVEL.
IY-UB-04	1/22/98	17:00	Medium dense, rusty brown sandy GRAVEL.
IY-UB-05	1/22/98	18:15	Medium dense, rusty brown sandy GRAVEL with abundant metal debris.
IY-UB-06	1/22/98	18:30	Medium dense rusty brown sandy GRAVEL with abundant metal debris.
IY-UB-10	1/22/98	19:00	Medium dense black over gray very sandy GRAVEL with sand blast-like material.
Bank			
IY-B-01	1/19/98	14:15	Light green gray dusting over medium stiff gravelly sandy SILT with abundant metal debris. Iron staining. Scattered shell fragments.
IY-B-02	1/19/98	14:30	Dark gray, medium dense silty gravelly SAND with apparent sand blast grit-like material. Iron staining and creosote like odor and sheen.
IY-B-03	1/21/98	14:45	Layer (2.5-cm) very soft green clayey SILT with shells over soft black SILT with occasional shell fragments. Trace metal and wood. Slight sheen.
IY-B-04	1/21/98	9:30	Layer (2.5-cm) light green clayey SILT with shells over black sandy gravelly SILT with abundant metal debris and moderate sheen.
IY-B-05	1/21/98	13:45	Layer (2.5-cm) green clayey SILT with shell fragments over very soft black SILT with abundant shell fragments with scattered metal and wood. Moderate sheen.
IY-B-06	1/20/98	15:00	Layer (2.5-cm) clayey SILT with shell fragments over very soft black clayey SILT with shell fragments. Trace gravel. Light sheen.

Table A-3 - Surface Sediment Sample Field Observations

Sample Location	Sample Date	Sample Time	Sediment Description
IY-B-07	1/20/98	10:00	Medium dense black, silty gravelly SAND with sheen and very slight creosote and diesel like odors.
IY-B-08	1/20/98	10:45	Medium dense black, silty gravelly SAND with abundant shell fragments and trace wood and metal debris.
IY-B-09	1/20/98	11:30	Medium stiff dark gray, slightly gravelly, sandy SILT with abundant shell fragment and wood fibers.
IY-B-10	1/20/98	12:00	Medium dense dark gray slightly gravelly slightly silty SAND with slight sheen, wood fragments, and scattered metal fragments.
IY-B-11	1/20/98	13:00	Medium dense black, slightly gravelly silty SAND with abundant shell fragments and trace wood. Slight sheen.
Side Slope			
IY-S-01	1/19/98	11:30	Dusting (1-cm) green clayey SILT over very soft, black SILT with shell fragments and wood fragments to 10-cm.
IY-S-02	1/19/98	12:45	Green SILT dusting over very soft, black, clayey SILT with shell and wood fragments.
IY-S-02	1/19/98	13:00	Green SILT dusting over very soft, black, clayey SILT with shell and wood fragments.
IY-S-03	1/21/98	10:00	Layer (2.5-cm) green clayey SILT with shell fragments over soft, black SILT with scattered shell fragments. Occasional wood splinters.
IY-S-04	1/21/98	11:15	Layer (2.5-cm) brown, green slightly sandy SILT with shell fragments over very soft, black, slightly sandy SILT with trace shells and wood splinters. Slight sheen.
IY-S-06	1/20/98	15:15	Layer (1 to 2.5-cm) very soft light green clayey SILT with shell fragments over very soft dark gray clayey SILT with shell fragments. Trace wood and gravels. Very slight sheen.

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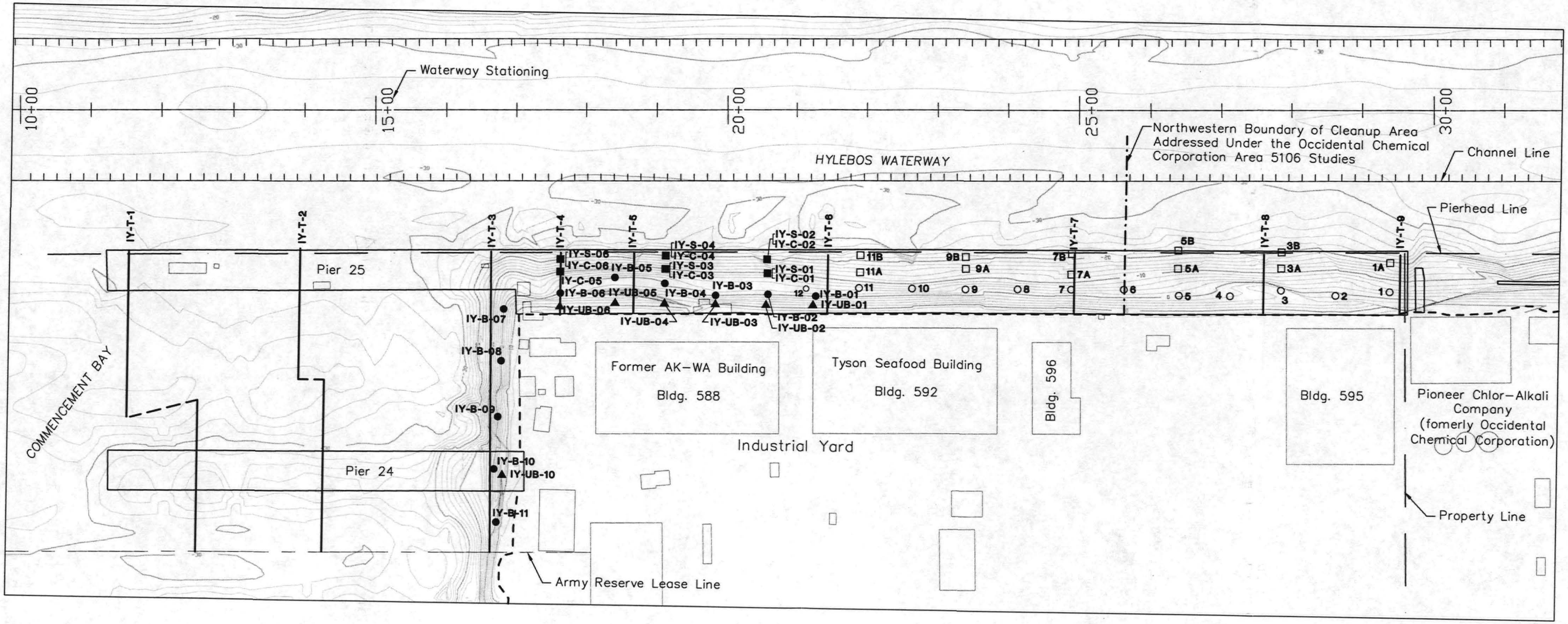
Confirmed Sample Location Plan
Port of Tacoma Industrial Yard



Port of Tacoma, 1998
Sample Location, Number, and Type (Depth)

● IY-B-01 Bank Sample (0 to 10 cm)

▲ IY-UB-01 Upper Bank (0 to 10 cm)

■ IY-S-01 / IY-C-01 Side Slope Surface Sample (0 to 10 cm) Collocated Subsurface Sample (0 to 3 ft)

IY-T-1 Approximate Diver Survey Transect Line Location and Number

Occidental Chemical Corporation, 1998
Sample Location, Number, and Type (Depth)

○ 10 Bank Sample (0 to 10 cm)

□ 7A Side Slope Surface Sample (0 to 10 cm) with Collocated Subsurface Sample (0 to 3 ft)

N

0 150 300
Scale in Feet

CVD 10/30/98 1=150 xref=Base and Contour wdstk.pc2
48580326

HARTCROWSER
J-4858-03 10/98
Figure A-1

Key to Exploration Logs

Sample Description

Classification of soils in this report is based on visual field and laboratory observations which include density/consistency, moisture condition, grain size, and plasticity estimates and should not be construed to imply field nor laboratory testing unless presented herein. Visual-manual classification methods of ASTM D 2488 were used as an identification guide.

Soil descriptions consist of the following:
Density/consistency, moisture, color, minor constituents, MAJOR CONSTITUENT, additional remarks.

Density/Consistency

Soil density/consistency in borings is related primarily to the Standard Penetration Resistance.
Soil density/consistency in test pits is estimated based on visual observation and is presented parenthetically on the test pit logs.

SAND or GRAVEL Density	Standard Penetration Resistance (N) in Blows/Foot	SILT or CLAY Consistency	Standard Penetration Resistance (N) in Blows/Foot	Approximate Shear Strength in TSF
Very loose	0 – 4	Very soft	0 – 2	<0.125
Loose	4 – 10	Soft	2 – 4	0.125 – 0.25
Medium dense	10 – 30	Medium stiff	4 – 8	0.25 – 0.5
Dense	30 – 50	Stiff	8 – 15	0.5 – 1.0
Very dense	>50	Very stiff	15 – 30	1.0 – 2.0
		Hard	>30	>2.0

Moisture

Dry	Little perceptible moisture
Damp	Some perceptible moisture, probably below optimum
Moist	Probably near optimum moisture content
Wet	Much perceptible moisture, probably above optimum

Minor Constituents

	Estimated Percentage
Not identified in description	0 – 5
Slightly (clayey, silty, etc.)	5 – 12
Clayey, silty, sandy, gravelly	12 – 30
Very (clayey, silty, etc.)	30 – 50

Legends

Sampling Test Symbols

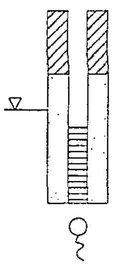
BORING SAMPLES

- ⊠ Split Spoon
- ⧅ Shelby Tube
- Cuttings
- Core Run
- * No Sample Recovery
- P Tube Pushed, Not Driven

TEST PIT SAMPLES

- ⊠ Grab (Jar)
- Bag
- ⧅ Shelby Tube

Groundwater Observations



Surface Seal

Groundwater Level on Date (ATD) At Time of Drilling

Observation Well Tip or Slotted Section

Groundwater Seepage (Test Pits)

Test Symbols

GS	Grain Size Classification
CN	Consolidation
TUU	Triaxial Unconsolidated Undrained
TCU	Triaxial Consolidated Undrained
TCD	Triaxial Consolidated Drained
QU	Unconfined Compression
DS	Direct Shear
K	Permeability
PP	Pocket Penetrometer Approximate Compressive Strength in TSF
TV	Torvane Approximate Shear Strength in TSF
CBR	California Bearing Ratio
MD	Moisture Density Relationship
AL	Atterberg Limits Water Content in Percent Liquid Limit Natural Plastic Limit
PID	Photoionization Detector Reading
CA	Chemical Analysis

HARTCROWSER

J-4858-03 8/98

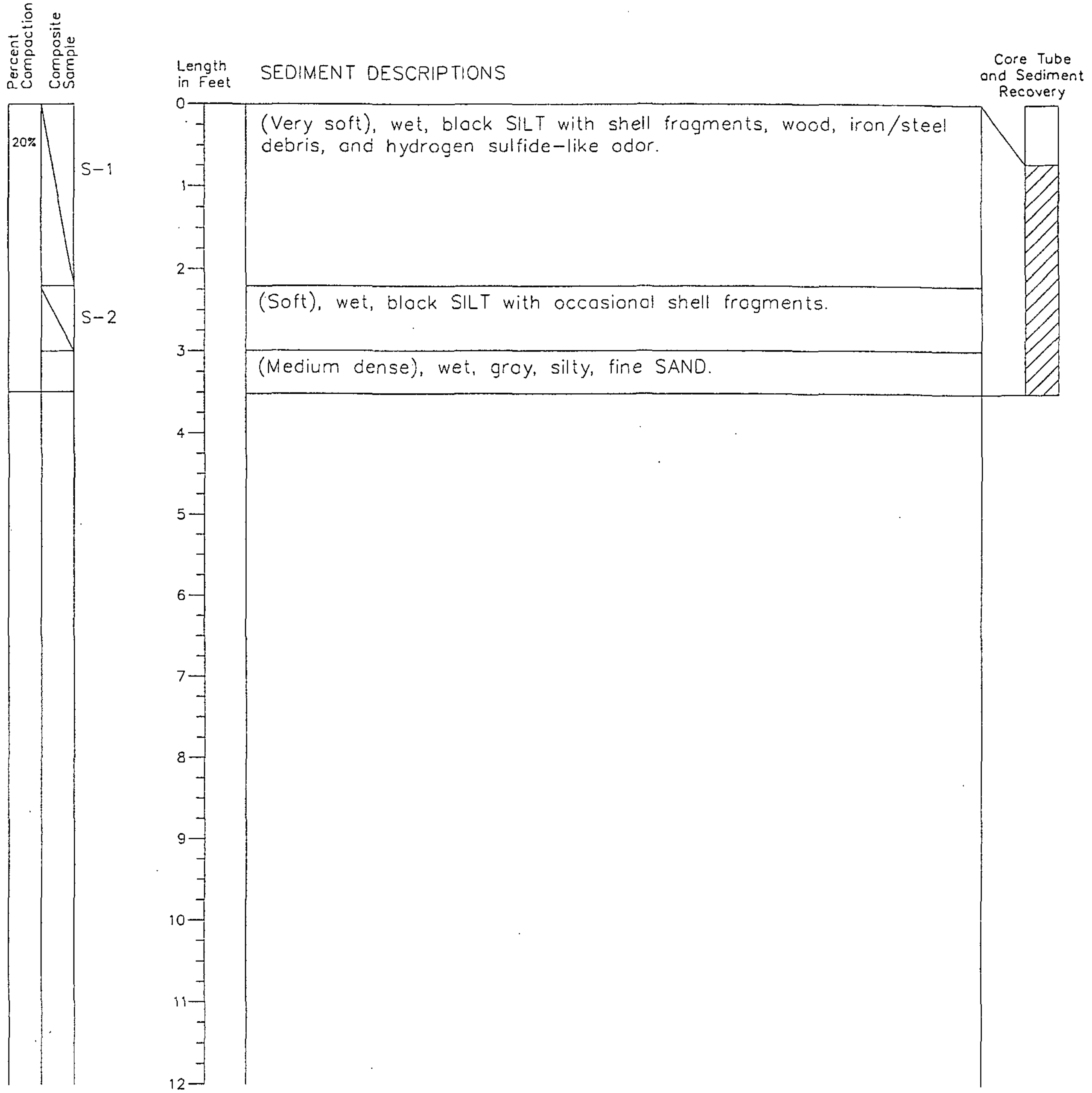
Figure A-2

1=1 BORING.DWG

Sediment Core Log IY-C-01

Type of Sample: Diver Core
Date/Time: 1/19/98
Recovery Length in Feet: 2.8
Mudline Elevation in Feet: −10.0

Northing:
Easting:
Drive Length in Feet: 3.5



Notes: 1. Horizontal control is based on NAD 83 datum (DGPS) and vertical control is based on MLLW datum.

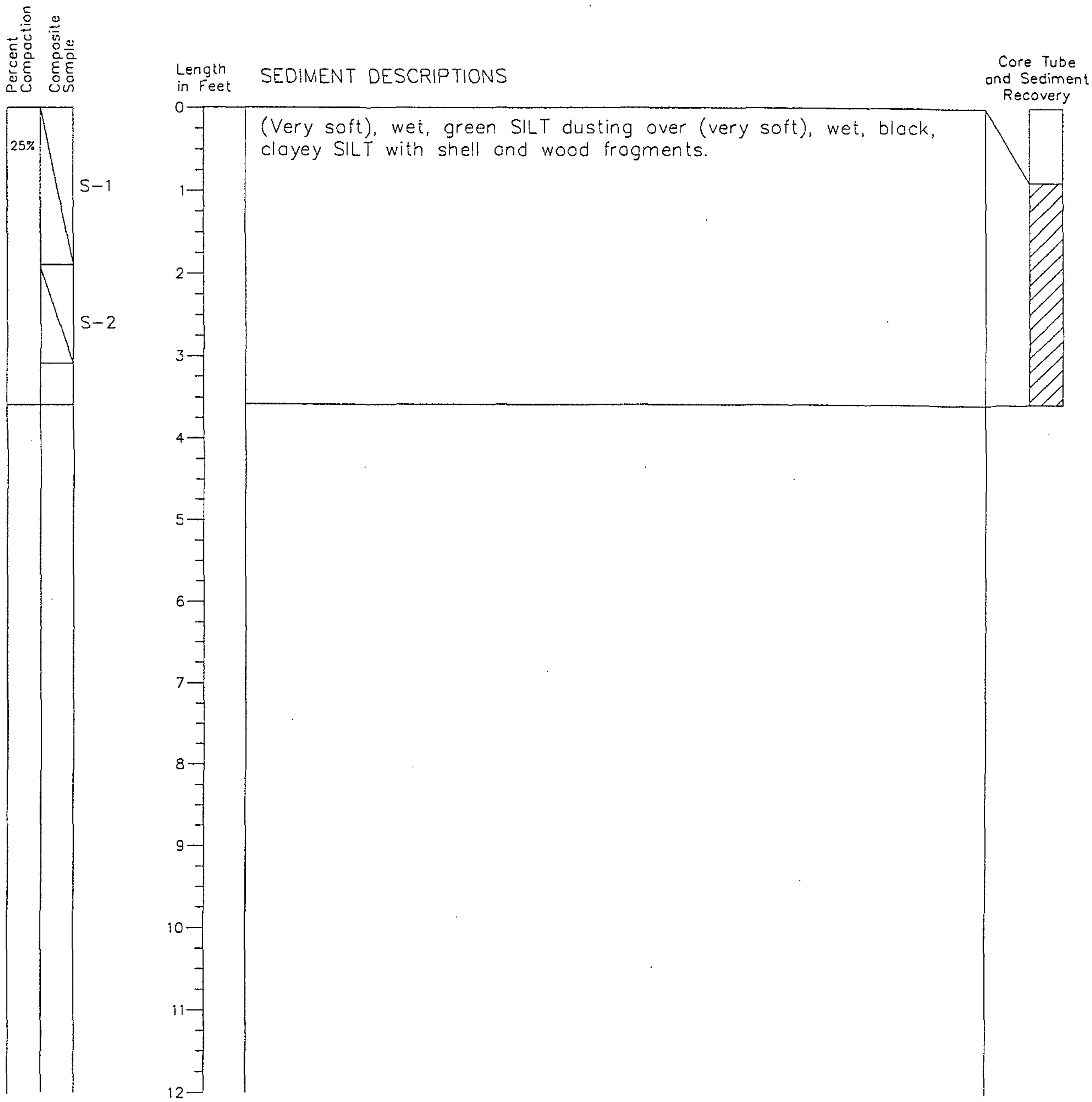
HARTCROWSER
J-4858-03 1/98
Figure A-3

1=1 ACAD LOG

Sediment Core Log IY-C-02

Type of Sample: Diver Core
Date/Time: 1/19/98
Recovery Length in Feet: 2.7
Mudline Elevation in Feet: −20.0

Northing:
Easting:
Drive Length in Feet: 3.6



Notes: 1. Horizontal control is based on NAD 83 datum (DGPS) and vertical control is based on MLLW datum.

HARTCROWSER
J-4858-03 1/98
Figure A-4

1=1 ACAD LOG

Sediment Core Log IY-C-03

Type of Sample: Diver Core
Date/Time: 1/21/98
Recovery Length in Feet: 2.8
Mudline Elevation in Feet: −10.0

Northing:
Easting:
Drive Length in Feet: 3.0

Percent Compaction	Composite Sample	Length in Feet	SEDIMENT DESCRIPTIONS
7%	S-1	0–1.8	(Very soft), wet, black, slightly sandy SILT with trace shell fragments, scattered wood splinters, metal debris, and hydrogen sulfide-like odor.
	S-2	1.8–3	1/2 inch green, clayey Silt lens over (soft), wet, black SILT with wood splinters.

Core Tube and Sediment Recovery

Length in Feet: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

Notes: 1. Horizontal control is based on NAD 83 datum (DGPS) and vertical control is based on MLLW datum.

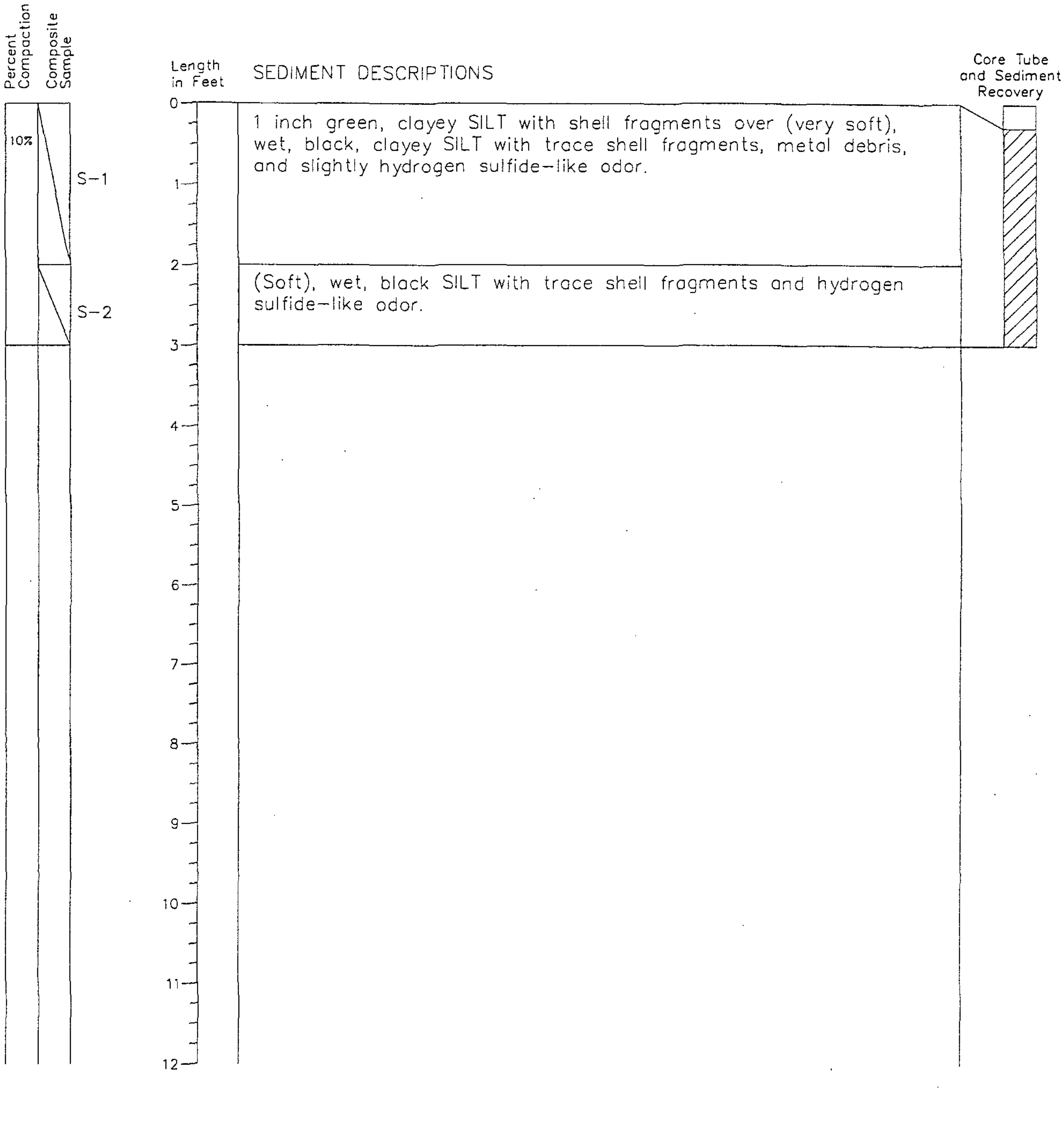
HARTCROWSER
J-4858-03 1/98
Figure A-5

1=1 ACAD LOG

Sediment Core Log IY-C-04

Type of Sample: Diver Core
Date/Time: 1/21/98
Recovery Length in Feet: 2.7
Mudline Elevation in Feet: −20.0

Northing:
Easting:
Drive Length in Feet: 3.0



Notes: 1. Horizontal control is based on NAD 83 datum (DGPS) and vertical control is based on MLLW datum.

1=1 ACAD LOG

HARTCROWSER
J-4858-03 1/98
Figure A-6

Sediment Core Log IY-C-05

Type of Sample: Diver Core
Date/Time: 1/20/98
Recovery Length in Feet: 2.8
Mudline Elevation in Feet: −10.0

Northing:
Easting:
Drive Length in Feet: 3.0

Percent Compaction	Composite Sample	Length in Feet	SEDIMENT DESCRIPTIONS	Core Tube and Sediment Recovery
10%	S-1	0	(Very soft), wet, dark gray, clayey SILT with abundant shell fragments, trace wood, metal, leaves, and twigs.	
		1		
	S-2		Hydrogen sulfide-like odor.	
		2		
		3		
		4		
		5		
		6		
		7		
		8		
		9		
		10		
		11		
		12		

Notes: 1. Horizontal control is based on NAD 83 datum (DGPS) and vertical control is based on MLLW datum.

1=1 ACAD LOG

HARTCROWSER
J-4858-03 1/98
Figure A-7

Sediment Core Log IY-C-06

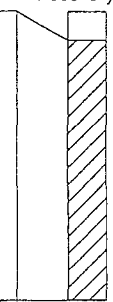
Type of Sample: Diver Core
Date/Time: 1/20/98
Recovery Length in Feet: 2.7
Mudline Elevation in Feet: −20.0

Northing:
Easting:
Drive Length in Feet: 3.0

Percent Compaction	Composite Sample	Length in Feet	SEDIMENT DESCRIPTIONS
10%	S-1	0	1/2 inch green, clayey SILT dusting over (soft), wet, black, clayey SILT with occasional shell fragments, wood, and trace metal.
		1.5	Moderate hydrogen sulfide-like odor.
	S-2	3	

Length in Feet: 0 1 2 3 4 5 6 7 8 9 10 11 12

Core Tube and Sediment Recovery



Notes: 1. Horizontal control is based on NAD 83 datum (DGPS) and vertical control is based on MLLW datum.

HARTCROWSER
J-4858-03 1/98
Figure A-8

1=1 ACAD LOG

APPENDIX B
DATA VALIDATION SUMMARY

APPENDIX B
DATA VALIDATION SUMMARY

B.1 Summary of Data Validation Effort

This appendix provides the quality assurance (QA) review of 37 sediment samples, including two field duplicates and two rinseate blanks collected from the Industrial Yard, located in the Hylebos Waterway of Commencement Bay.

Chemical analyses were performed by Columbia Analytical Services of Kelso, WA and Analytical Resources Inc. of Seattle, WA. The laboratory submitted data packages were reviewed by Hart Crowser. The following criteria were evaluated in the standard validation process:

- Holding Times;
- Method Blanks;
- Surrogate Recoveries;
- Blank Spike and Laboratory Control Sample Recoveries;
- Matrix Spike/Matrix Spike Duplicate(MS/MSD) Recoveries and Relative Percent Differences (RPD);
- Laboratory Duplicate Relative Percent Differences (RPDs);
- Field Duplicate Relative Percent Differences (RPDs); and
- Reported Detection Limits.

B.2 Overall Data Quality

The overall data quality objectives (DQOs), as set forth in the QAPP were met, and subsequently, the data for collected during this study of the site considered are acceptable for use as qualified. The completeness for the associated data is 100 percent. Detailed discussions are presented below.

Quality Assurance Objectives

Precision. Precision measures the reproducibility of measurements under a given set of conditions. Specifically, it is a quantitative measure of the variability of a group of measurements compared to their average values. Precision is generally evaluated using both MS/MSD (or lab duplicate) results and field duplicate results. MS/MSD and lab duplicate results provide information on laboratory (only) precision, while field duplicates provide information on field and lab precision combined.

Analytical precision is measured through matrix spike/matrix spike duplicate (MS/MSD) samples for organics analyses, and lab duplicate samples for metals and other inorganic analyses. Analytical precision is quantitatively expressed as the relative percent difference (RPD) between the MS/MSD or lab duplicates. Analytical precision measurements were carried out on project-specific soil and groundwater samples at a minimum frequency of one in 20 samples. Data qualifiers were assigned to metals results based on high laboratory duplicate RPDs for arsenic, copper, lead, mercury, and zinc.

Two sets of field duplicates (homogenized samples) were collected and analyzed for this site. The project-specific precision acceptance criteria for field duplicates was 75 percent RPD. The field duplicate precision for all analyses were generally acceptable. The RPDs for Aroclor 1260 and several semivolatile compounds exceeded the criteria of 75%. However, no qualifiers were assigned based on the RPD results alone.

Accuracy. Accuracy measures the closeness of the measured value to the true value. The accuracy of chemical test results was assessed by analyzing standard reference materials or by "spiking" samples with known standards (surrogates, laboratory control samples, blank spikes, and/or matrix spike) and measuring the percent recovery.

Accuracy measurements for all fractions were carried out in accordance with CLP SOW requirements for organic and inorganic analyses and at a minimum frequency of one in 20 samples. Recoveries of surrogates, MS/MSDs, and laboratory control samples (LCSs) were generally acceptable. Data qualifiers were required for pesticide/PCBs and metals results due to surrogate and matrix spike recoveries outside control limits.

Completeness. Completeness is defined as the percentage of measurements made which are judged to be valid measurements. The completeness of the data is the ratio of acceptable data points to the total number of data points (expressed as a percent). A target completeness goal for this work was 100 percent. There were 2097 data points and no data were rejected; therefore, the completeness of the data for this project was 100 percent.

Comparability. Comparability is a qualitative parameter expressing the confidence with which one data set can be compared with another. Because of the use of standard techniques for both sample collection and laboratory analysis, the data collected from same sampling locations and depths should be comparable to both internal and other data generated.

B.3 Major Problems Encountered

In general, detection limits were below Sediment Quality Objective (SQOs) with following exceptions. Method 8080 was not used for the analysis of hexachlorobenzene and hexachlorobutadiene. As a result, the detection limits for these compounds were above SQOs in several samples. Detection limits for some semivolatiles and pesticide/PCBs were elevated above SQOs due to matrix interferences and high concentrations of target compounds in the samples which required dilutions.

B.4 Minor Problems Encountered

Semivolatile Organic Analyses. Bis(2-ethylhexyl)phthalate was detected in method blank for water samples. Rinseate blank results were qualified as not detected (U). Surrogate recoveries of p-terphenyl and 2-fluorobiphenyl were outside laboratory control limits. No qualifiers were assigned since other surrogate recoveries were within control limits.

Pesticide/PCBs Analyses. Hexachlorobenzene was detected in the method blank. Associated sample results were qualified as not detected (U). Surrogate recoveries of tetrachloro-m-xylene or decachlorobiphenyl in several samples were outside laboratory control limits. Only sample results for IY-0S-01, IY-B-04, IY-UB-03, and IY-UB-06 were qualified as estimated (UJ/J) since both surrogate recoveries were outside control limits. MS/MSD recoveries for 4,4'-DDE were above control limits. No qualifiers were assigned based on MS/MSD recoveries alone.

Total Organic Carbon Analyses. No problems were encountered.

Metals Analyses. The recommended holding time for mercury analysis was exceeded by 5 days in sample IY-UB-05. The result was qualified as estimated (J). One or more matrix spike recoveries for arsenic, copper, lead, mercury, and zinc were outside laboratory control limits. Associated sample results were qualified as estimated (J). One or more laboratory duplicate RPDs for arsenic, copper, lead, mercury, and zinc were above control limits. Associated sample results were qualified as estimated (J).

Rinseate Blanks. Two rinseate blanks were collected in association with sediment sampling. Analyzed constituents were not present at detectable concentrations in either sample.

Data Qualifier Definitions

The following data qualifiers have been used in the text and tables based on a quality assurance review of the laboratory procedures and results:

U - Indicates the compound or analyte was analyzed for and not detected. The value reported is the sample quantitation limit corrected for sample dilution and moisture content by the laboratory.

UJ - Indicates the compound or analyte was analyzed for and not detected. Due to quality control deficiencies identified during data validation the value reported may not accurately reflect the sample quantitation limit.

J - Indicates the compound or analyte was analyzed for and detected. The associated value is estimated but the data are usable for decision making processes.

$\boxed{}$ Boxed value exceeds SQO for specified analyte.

Table B-1 - Analytical Results for Surface Side Slope Samples

Sample ID		IY-S-01	IY-S-02	IY-S-03	IY-S-80
Sampling Date		1/19/98	1/19/98	1/21/98	1/21/98
Depth Interval	SQO	0 to 10 cm	0 to 10 cm	0 to 10 cm	0 to 10 cm
					Dup of IY-S-03
Conventionals in %					
Total Organic Carbon		2	2.1	2.2	2
Total Solids		47.1	47.5	45.4	44.3
Metals in mg/kg					
Arsenic	57	34.1	17.1	20.1 J	23.6 J
Cadmium	5.1	1.1 U	8.6	1.2 U	1.2 U
Copper	390	487 J	119 J	220 J	222 J
Lead	450	208 J	44.4 J	74.4 J	90.4 J
Mercury	0.59	0.53	0.14 J	0.27	0.27
Zinc	410	1210 J	5130 J	286 J	286 J
Pesticide/PCBs in µg/kg					
Aroclor 1016		19 U	18 U	19 U	19 U
Aroclor 1221		37 U	37 U	38 U	38 U
Aroclor 1232		19 U	18 U	19 U	19 U
Aroclor 1242		19 U	18 U	19 U	19 U
Aroclor 1248		19 U	18 U	19 U	19 U
Aroclor 1254		19 U	18 U	19 U	19 U
Aroclor 1260		290	18 U	94 U	130
Total PCBs	300	290	37 U	94 U	130
4,4'-DDE	9	3.5 U	1.8 U	2.4 U	3.4 U
4,4'-DDD	16	8.8	5.7	7	6.7
4,4'-DDT	34	15 U	1.8 U	16 U	1.9 U
Phenols in µg/kg					
Phenol	420	56	26	200 U	24
2-Methylphenol	63	19 U	19 U	*200 U*	20 U
4-Methylphenol	670	24	19 U	200 U	20 U
2,4-Dimethylphenol	29	19 U	19 U	*200 U*	20 U
Pentachlorophenol	360	97 U	96 U	*980 U*	99 U
LPAHs in µg/kg					
2-Methylnaphthalene	670	140	72	210	68
Acenaphthene	500	230	360	400	72
Acenaphthylene	1300	100	200	200 U	120
Anthracene	960	740	2100	2200	780
Fluorene	540	280	370	610	200
Naphthalene	2100	74	78	220	60
Phenanthrene	1500	1500	2400	3900	810
LPAHs	5200	3064	5580	7540	2110
HPAHs in µg/kg					
Benzo(a)anthracene	1600	2100	3300	4000	2000
Benzo(a)pyrene	1600	2600	2900	3100	2300
Benzo(b)fluoranthene		3300	3400	4200	3200
Benzo(k)fluoranthene		2400	2800	3100	2500

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Table B-1 - Analytical Results for Surface Side Slope Samples

	SQO				
Sample ID		IY-S-01	IY-S-02	IY-S-03	IY-S-80
Sampling Date		1/19/98	1/19/98	1/21/98	1/21/98
Depth Interval	SQO	0 to 10 cm	0 to 10 cm	0 to 10 cm	0 to 10 cm
					Dup of IY-S-03
Total Benzofluoranthenes	3600	5700	6200	7300	5700
Benzo(g,h,i)perylene	*720*	*710*	*880*	*1300*	*500*
Chrysene	2800	3400	4900	4600	3100
Dibenz(a,h)anthracene	230	580	680	440	430
Fluoranthene	2500	4600	12000	7000	3600
Indeno(1,2,3-cd)pyrene	690	1000	1300	1700	820
Pyrene	3300	4600	5600	6000	3700
HPAHs	17000	20690	32160	29440	18450
Chlorinated Aromatics in µg/kg					
1,3-Dichlorobenzene	170	19 U	19 U	*200 U*	20 U
1,4-Dichlorobenzene	110	19 U	19	*200 U*	20 U
1,2-Dichlorobenzene	50	19 U	19 U	*200 U*	20 U
1,2,4-Trichlorobenzene	51	19 U	19 U	*200 U*	20 U
Hexachlorobenzene	22	9.7	7.8	0.94 U	7.1
Chlorinated Aliphatics in µg/kg					
Hexachlorobutadiene	11	12 U	10 U	8.5 U	11 U
Phthalates in µg/kg					
Dimethylphthalate	160	26	19 U	*200 U*	20 U
Diethylphthalate	*200*	*19 U*	*19 U*	200 U	20 U
Di-n-butylphthalate	1400	26	19 U	200 U	24
Butylbenzylphthalate	900	94	19 U	200 U	46
Bis(2-Ethylhexyl)phthalate	1300	980	480	3600	1100
Di-n-octylphthalate	6200	19 U	19 U	200 U	26
Other Organic Compounds					
Benzyl Alcohol	73	19 U	19 U	*200 U*	20 U
Benzoic Acid	650	190 U	190 U	*2000 U*	200 U
Dibenzofuran	540	170	200	260	92
N-Nitrosodiphenylamine	28	19 U	19 U	*200 U*	20 U
Hexachloroethane		19 U	19 U	200 U	20 U

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Table B-1 - Analytical Results for Surface Side Slope Samples

Sample ID		IY-S-04	IY-S-06
Sampling Date		1/21/98	1/20/98
Depth Interval	SQO	0 to 10 cm	0 to 10 cm
Conventionals in %			
Total Organic Carbon		2.4	1.9
Total Solids		46.5	46.6
Metals in mg/kg			
Arsenic	57	20.7 J	13.2
Cadmium	5.1	1.2 U	1.1 U
Copper	390	150 J	160 J
Lead	450	59.7 J	39.2 J
Mercury	0.59	0.12 J	0.38
Zinc	410	168 J	141 J
Pesticide/PCBs in µg/kg			
Aroclor 1016		20 U	19 U
Aroclor 1221		40 U	38 U
Aroclor 1232		20 U	19 U
Aroclor 1242		20 U	19 U
Aroclor 1248		20 U	19 U
Aroclor 1254		20 U	19 U
Aroclor 1260		200 U	110 U
Total PCBs	300	200 U	110 U
4,4'-DDE	9	2.5 U	2 U
4,4'-DDD	16	6	3.1
4,4'-DDT	34	2 U	6.9 U
Phenols in µg/kg			
Phenol	420	25	210
2-Methylphenol	63	20 U	38 U
4-Methylphenol	670	20 U	38 U
2,4-Dimethylphenol	29	20 U	*38 U*
Pentachlorophenol	360	99 U	190 U
LPAHs in µg/kg			
2-Methylnaphthalene	670	91	54
Acenaphthene	500	220	140
Acenaphthylene	1300	370	97
Anthracene	960	$\boxed{7000}$	820
Fluorene	540	320	200
Naphthalene	2100	77	100
Phenanthrene	1500	$\boxed{2000}$	820
LPAHs	5200	10078	2231
HPAHs in µg/kg			
Benzo(a)anthracene	1600	$\boxed{7300}$	1400
Benzo(a)pyrene	1600	$\boxed{5200}$	1300
Benzo(b)fluoranthene		5600	1700
Benzo(k)fluoranthene		5400	1200

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Table B-1 - Analytical Results for Surface Side Slope Samples

Sample ID		IY-S-04	IY-S-06
Sampling Date		1/21/98	1/20/98
Depth Interval	SQO	0 to 10 cm	0 to 10 cm
Total Benzofluoranthenes	3600	$\boxed{11000}$	2900
Benzo(g,h,i)perylene	720	$\boxed{1100}$	440
Chrysene	2800	$\boxed{8900}$	1400
Dibenz(a,h)anthracene	230	$\boxed{970}$	230
Fluoranthene	2500	$\boxed{31000}$	$\boxed{3000}$
Indeno(1,2,3-cd)pyrene	690	$\boxed{1800}$	$\boxed{700}$
Pyrene	3300	$\boxed{22000}$	2200
HPAHs	17000	$\boxed{67270}$	11370
Chlorinated Aromatics in µg/kg			
1,3-Dichlorobenzene	170	20 U	38 U
1,4-Dichlorobenzene	*110*	*20 U*	*38 U*
1,2-Dichlorobenzene	50	20 U	38 U
1,2,4-Trichlorobenzene	51	20 U	38 U
Hexachlorobenzene	22	7.2	0.95 U
Chlorinated Aliphatics in µg/kg			
Hexachlorobutadiene	11	11	7.7 U
Phthalates in µg/kg			
Dimethylphthalate	160	20 U	38 U
Diethylphthalate	200	20 U	38 U
Di-n-butylphthalate	1400	29	38 U
Butylbenzylphthalate	900	20 U	60 M
Bis(2-Ethylhexyl)phthalate	*1300*	*700*	*610*
Di-n-octylphthalate	6200	20 U	38 U
Other Organic Compounds			
Benzyl Alcohol	73	50	38 U
Benzoic Acid	650	200 U	380 U
Dibenzofuran	540	160	130
N-Nitrosodiphenylamine	28	20 U	*38 U*
Hexachloroethane		20 U	38 U

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Table B-2 - Analytical Results for Subsurface Side Slope Samples

Sample ID		IY-C-01-S1	IY-C-01-S2	IY-C-02-S1	IY-C-02-S2	IY-C-03-S1
Sampling Date		1/19/98	1/19/98	1/19/98	1/19/98	1/21/98
Depth Interval	SQO	0 to 2	2 to 3	0 to 1.8	1.8 to 3	0 to 1.75
Conventionals in %						
Total Organic Carbon		3.5	4.1	2.6	3.1	2.6
Total Solids		45.9	57.2	46.7	48.7	47.8
Metals in mg/kg						
Arsenic	57	50	49.5	19.8	39.7	
Cadmium	5.1	1.6 J	1.7	1.1 U	1.1 U	
Copper	390	428 J	566 J	171 J	323 J	
Lead	450	517	371	99.1	239	
Mercury	0.59	1.1 J	3 J	0.12 J	0.09 J	
Zinc	410	1240 J	464 J	276 J	788 J	
Pesticide/PCBs in µg/kg						
Aroclor 1016		98 U	97 U	19 U	19 UJ	19 U
Aroclor 1221		200 U	190 U	37 U	39 UJ	39 U
Aroclor 1232		98 U	97 U	19 U	19 UJ	19 U
Aroclor 1242		98 U	97 U	19 U	19 UJ	19 U
Aroclor 1248		98 U	97 U	19 U	19 UJ	19 U
Aroclor 1254		420	220	19 U	85 J	19 U
Aroclor 1260		1000	580	19 U	180 J	180
Total PCBs	300	1420	800	37 U	265 J	180
4,4'-DDE	9	*12 U*	*17 U*	1.9 U	1.9 UJ	2.2 U
4,4'-DDD	16	23	71	5.5	10 J	5.4
4,4'-DDT	34	9.8 U	64	5.8 U	7.2 UJ	7.3 U
Phenols in µg/kg						
Phenol	420	180	58 U	140	57 U	58 U
2-Methylphenol	63	20 U	58 U	58 U	57 U	58 U
4-Methylphenol	670	20 U	58 U	58 U	57 U	58 U
2,4-Dimethylphenol	29	20 U	*58 U*	*58 U*	*57 U*	*58 U*
Pentachlorophenol	360	98 U	290 U	290 U	290 U	290 U
LPAHs in µg/kg						
2-Methylnaphthalene	670	43	1200	450	68	58 U
Acenaphthene	500	75	1200	430	810	68
Acenaphthylene	1300	64	130	110	57 U	86
Anthracene	960	360	3000	2700	380	590
Fluorene	540	100	1800	770	310	140
Naphthalene	2100	65	800	230	1000	70
Phenanthrene	1500	620	10000	5600	860	800
LPAHs	5200	1327	18130	10290	3428	1754
HPAHs in µg/kg						
Pyrene	3300	2800	23000	8200	3300	3000
Benzo(a)anthracene	1600	800	3900	3700	770	1500
Chrysene	2800	1200	7100	4700	1200	2300
Benzo(b)fluoranthene		1700	5500	3400	1600	2500

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Table B-2 - Analytical Results for Subsurface Side Slope Samples

Sample ID		IY-C-01-S1	IY-C-01-S2	IY-C-02-S1	IY-C-02-S2	IY-C-03-S1
Sampling Date		1/19/98	1/19/98	1/19/98	1/19/98	1/21/98
Depth Interval	SQO	0 to 2	2 to 3	0 to 1.8	1.8 to 3	0 to 1.75
Benzo(k)fluoranthene		1100	4000	2100	920	1400
Total Benzofluoranthenes	3600	2800	$\boxed{9500}$	$\boxed{5500}$	2520	$\boxed{3900}$
Benzo(a)pyrene	1600	1400	$\boxed{6300}$	$\boxed{3000}$	1200	$\boxed{1900}$
Indeno(1,2,3-cd)pyrene	690	$\boxed{930}$	$\boxed{2600}$	$\boxed{1300}$	640	$\boxed{970}$
Dibenz(a,h)anthracene	230	$\boxed{470}$	$\boxed{1600}$	$\boxed{800}$	$\boxed{350}$	$\boxed{530}$
Fluoranthene	2500	760	$\boxed{3200}$	$\boxed{10000}$	1700	2400
Benzo(g,h,i)perylene	720	$\boxed{890}$	$\boxed{2400}$	$\boxed{1100}$	550	$\boxed{850}$
HPAHs	17000	12050	$\boxed{59600}$	$\boxed{38300}$	12230	$\boxed{17350}$
Chlorinated Aromatics in µg/kg						
1,3-Dichlorobenzene	170	20 U	58 U	58 U	57 U	58 U
1,4-Dichlorobenzene	110	20 U	58 U	58 U	57 U	58 U
1,2-Dichlorobenzene	50	20 U	*58 U*	*58 U*	*57 U*	*58 U*
1,2,4-Trichlorobenzene	51	20 U	*58 U*	*58 U*	*57 U*	*58 U*
Hexachlorobenzene	22	18	$\boxed{36}$	5.6	10 J	5.5
Chlorinated Aliphatics in µg/kg						
Hexachlorobutadiene	11	$\boxed{29}$	$\boxed{84}$	9.1	11 J	11
Phthalates in µg/kg						
Dimethylphthalate	160	34	58 U	58 U	57 U	58 U
Diethylphthalate	200	20 U	58 U	58 U	57 U	58 U
Di-n-butylphthalate	1400	20 U	58 U	58 U	57 U	58 U
Butylbenzylphthalate	900	20 U	58 U	58 U	60	58 U
Bis(2-Ethylhexyl)phthalate	1300	920	840	730	890	1100
Di-n-octylphthalate	6200	20 U	58 U	58 U	57 U	58 U
Other Organic Compounds						
Benzyl Alcohol	73	20 U	58 U	58 U	57 U	58 U
Benzoic Acid	650	200 U	580 U	580 U	570 U	580 U
Dibenzofuran	540	65	500	180	340	70
N-Nitrosodiphenylamine	28	20 U	*58 U*	*58 U*	*57 U*	*58 U*

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Table B-2 - Analytical Results for Subsurface Side Slope Samples

Sample ID		IY-C-03-S2	IY-C-04-S1	IY-C-04-S2	IY-C-05-S1	IY-C-05-S2
Sampling Date		1/21/98	1/21/98	1/21/98	1/20/98	1/20/98
Depth Interval	SQO	1.75 to 3	0 to 2	2 to 3	0 to 1.5	1.5 to 3
Conventionals in %						
Total Organic Carbon		2.8	3	2.6	2.5	4
Total Solids		55.5	47.5	47.2	51.5	49.5
Metals in mg/kg						
Arsenic	57				37.8 J	40.8
Cadmium	5.1				1.4 J	1.8 J
Copper	390				609	151
Lead	450				144	1040 J
Mercury	0.59				0.33 J	1.5 J
Zinc	410				668	287
Pesticide/PCBs in µg/kg						
Aroclor 1016		19 UJ	18 U	20 UJ	20 UJ	19 UJ
Aroclor 1221		37 UJ	36 U	40 UJ	39 UJ	39 UJ
Aroclor 1232		19 UJ	18 U	20 UJ	20 UJ	19 UJ
Aroclor 1242		19 UJ	18 U	20 UJ	20 UJ	19 UJ
Aroclor 1248		19 UJ	18 U	20 UJ	20 UJ	19 UJ
Aroclor 1254		200 J	69	74 J	53 UJ	400 J
Aroclor 1260		160 J	85	170 J	100 J	530 J
Total PCBs	300	360 J	154	244 J	100 J	930 J
4,4'-DDE	9	5.6 J	3 U	3.4 UJ	3 UJ	21 J
4,4'-DDD	16	19 J	3.8 U	5.6 UJ	4.6 UJ	67 J
4,4'-DDT	34	6.3 UJ	7.6	9.3 UJ	11 J	19 UJ
Phenols in µg/kg						
Phenol	420	60 U	58 U	59 U	250	59 U
2-Methylphenol	63	60 U	58 U	59 U	57 U	59 U
4-Methylphenol	670	60 U	58 U	59 U	57 U	59 U
2,4-Dimethylphenol	29	*60 U*	*58 U*	*59 U*	*57 U*	*59 U*
Pentachlorophenol	360	300 U	290 U	290 U	280 U	300 U
LPAHs in µg/kg						
2-Methylnaphthalene	670	760	58 U	59 U	140	2100
Acenaphthene	500	950	58 U	59 U	120	1500
Acenaphthylene	1300	280	180	89	58	150
Anthracene	960	2500	1100	300	580	3900
Fluorene	540	1100	180	61	140	2000
Naphthalene	2100	1500	64	67	74	1000
Phenanthrene	1500	11000	700	400	1200	15000
LPAHs	5200	18090	2224	917	2312	25650
HPAHs in µg/kg						
Pyrene	3300	20000	3400	2600	3900	21000
Benzo(a)anthracene	1600	6100	1300	680	1400	5600
Chrysene	2800	7800	2200	1400	2300	7800
Benzo(b)fluoranthene		4800	2600	1700	1900	6000

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Table B-2 - Analytical Results for Subsurface Side Slope Samples

Sample ID		IY-C-03-S2	IY-C-04-S1	IY-C-04-S2	IY-C-05-S1	IY-C-05-S2
Sampling Date		1/21/98	1/21/98	1/21/98	1/20/98	1/20/98
Depth Interval	SQO	1.75 to 3	0 to 2	2 to 3	0 to 1.5	1.5 to 3
Benzo(k)fluoranthene		3000	1700	1600	1900	3700
Total Benzofluoranthenes	3600	7800	4300	3300	3800	9700
Benzo(a)pyrene	1600	7500	2200	1600	1800	7500
Indeno(1,2,3-cd)pyrene	690	3300	1000	760	880	3000
Dibenz(a,h)anthracene	230	1800	580	420	470	1700
Fluoranthene	2500	13000	1600	950	3000	8900
Benzo(g,h,i)perylene	720	3400	870	650	740	3000
HPAHs	17000	70700	17450	12360	18290	68200
Chlorinated Aromatics in µg/kg						
1,3-Dichlorobenzene	170	60 U	58 U	59 U	57 U	59 U
1,4-Dichlorobenzene	110	60 U	58 U	59 U	57 U	59 U
1,2-Dichlorobenzene	50	*60 U*	*58 U*	*59 U*	*57 U*	*59 U*
1,2,4-Trichlorobenzene	51	*60 U*	*58 U*	*59 U*	*57 U*	*59 U*
Hexachlorobenzene	22	6.8 J	7.1	8.8 J	9.1 J	25 J
Chlorinated Aliphatics in µg/kg						
Hexachlorobutadiene	11	*14 UJ*	10	14 J	5.5 J	51 J
Phthalates in µg/kg						
Dimethylphthalate	160	60 U	58 U	59 U	57 U	59 U
Diethylphthalate	200	60 U	58 U	59 U	57 U	59 U
Di-n-butylphthalate	1400	60 U	58 U	59 U	57 U	59 U
Butylbenzylphthalate	900	60 U	58 U	100	69	59 U
Bis(2-Ethylhexyl)phthalate	1300	430	850	900	1900	3300
Di-n-octylphthalate	6200	60 U	58 U	59 U	57 U	59 U
Other Organic Compounds						
Benzyl Alcohol	73	60 U	58 U	59 U	57 U	59 U
Benzoic Acid	650	600 U	580 U	590 U	570 U	590 U
Dibenzofuran	540	160	84	59 U	74	360
N-Nitrosodiphenylamine	28	*60 U*	*58 U*	*59 U*	*57 U*	*59 U*

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Table B-2 - Analytical Results for Subsurface Side Slope Samples

	SQO		
Sample ID		IY-C-06-S1	IY-C-06-S2
Sampling Date		1/20/98	1/20/98
Depth Interval	SQO	0 to 1.5	1.5 to 3
Conventionals in %			
Total Organic Carbon		2.1	2.4
Total Solids		47.5	50.1
Metals in mg/kg			
Arsenic	57		
Cadmium	5.1		
Copper	390		
Lead	450		
Mercury	0.59		
Zinc	410		
Pesticide/PCBs in µg/kg			
Aroclor 1016		19 UJ	19 UJ
Aroclor 1221		37 UJ	39 UJ
Aroclor 1232		19 UJ	19 UJ
Aroclor 1242		19 UJ	19 UJ
Aroclor 1248		19 UJ	19 UJ
Aroclor 1254		55 J	93 J
Aroclor 1260		46 J	110 J
Total PCBs	300	101 J	203 J
4,4'-DDE	9	2.7 UJ	3.2 UJ
4,4'-DDD	16	2.9 UJ	5.6 UJ
4,4'-DDT	34	5.9 J	6.5 J
Phenols in µg/kg			
Phenol	420	59 U	58 U
2-Methylphenol	63	59 U	58 U
4-Methylphenol	670	59 U	58 U
2,4-Dimethylphenol	29	*59 U*	*58 U*
Pentachlorophenol	360	300 U	290 U
LPAHs in µg/kg			
2-Methylnaphthalene	670	59 U	58 U
Acenaphthene	500	79	93
Acenaphthylene	1300	59 U	59
Anthracene	960	460	300
Fluorene	540	120	120
Naphthalene	2100	63	110
Phenanthrene	1500	650	800
LPAHs	5200	1372	1482
HPAHs in µg/kg			
Pyrene	3300	$\boxed{3600}$	$\boxed{3600}$
Benzo(a)anthracene	1600	830	690
Chrysene	2800	1500	1300
Benzo(b)fluoranthene		1500	1700

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Table B-2 - Analytical Results for Subsurface Side Slope Samples

Sample ID		IY-C-06-S1	IY-C-06-S2
Sampling Date		1/20/98	1/20/98
Depth Interval	SQO	0 to 1.5	1.5 to 3
Benzo(k)fluoranthene		1400	1600
Total Benzofluoranthenes	3600	2900	3300
Benzo(a)pyrene	1600	1200	1500
Indeno(1,2,3-cd)pyrene	690	540	$\boxed{710}$
Dibenz(a,h)anthracene	230	230	$\boxed{320}$
Fluoranthene	2500	2000	1400
Benzo(g,h,i)perylene	720	450	590
HPAHs	17000	13250	13410
Chlorinated Aromatics in µg/kg			
1,3-Dichlorobenzene	170	59 U	58 U
1,4-Dichlorobenzene	110	59 U	58 U
1,2-Dichlorobenzene	50	*59 U*	*58 U*
1,2,4-Trichlorobenzene	51	*59 U*	*58 U*
Hexachlorobenzene	22	6.4 J	12 J
Chlorinated Aliphatics in µg/kg			
Hexachlorobutadiene	11	11 J	0.96 UJ
Phthalates in µg/kg			
Dimethylphthalate	160	59 U	58 U
Diethylphthalate	200	59 U	58 U
Di-n-butylphthalate	1400	59 U	58 U
Butylbenzylphthalate	900	59 U	82
Bis(2-Ethylhexyl)phthalate	1300	$\boxed{1400}$	1200
Di-n-octylphthalate	6200	78	58 U
Other Organic Compounds			
Benzyl Alcohol	73	59 U	58 U
Benzoic Acid	650	590 U	580 U
Dibenzofuran	540	73	88
N-Nitrosodiphenylamine	28	*59 U*	*58 U*

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Table B-3 - Analytical Results for Bank Samples

Sample ID		IY-B-01	IY-B-02	IY-B-03	IY-B-04	IY-B-80
Sampling Date		1/19/98	1/19/98	1/21/98	1/21/98	1/21/98
Depth Interval	SQO	0 to 10 cm	0 to 10 cm	0 to 10 cm	0 to 10 cm	0 to 10 cm Dup of IY-B-04
Conventionals in %						
Total Organic Carbon		2.6	1.2	2.7	2.2	2.1
Total Solids		59.6	74.3	51.4	63.9	61.2
Metals in mg/kg						
Arsenic	57	39.3	66.7	29.7 J	55.1	32.9
Cadmium	5.1	0.86 U	0.69 U	0.97 U	0.81 U	0.85 U
Copper	390	338 J	1690 J	310 J	260 J	257 J
Lead	450	390 J	313 J	384 J	204 J	160 J
Mercury	0.59	1.1	0.14	0.45	0.21	0.19
Zinc	410	855 J	5160 J	704 J	444 J	446 J
Pesticide/PCBs in µg/kg						
Aroclor 1016		650 U	530 U	19 U	18 UJ	19 U
Aroclor 1221		1300 U	1100 U	37 U	36 UJ	38 U
Aroclor 1232		650 U	530 U	19 U	18 UJ	19 U
Aroclor 1242		650 U	530 U	19 U	18 UJ	19 U
Aroclor 1248		650 U	530 U	19 U	18 UJ	19 U
Aroclor 1254		650 U	530 U	74 U	18 UJ	19 U
Aroclor 1260		8100	710	510	110 J	270
Total PCBs	300	8100	710	510	110 J	270
4,4'-DDE	9	*65 U*	*53 U*	8.1 U	1.8 UJ	1.9 U
4,4'-DDD	16	*65 U*	*53 U*	12	11 J	7.2
4,4'-DDT	34	150	*53 U*	15 U	26 J	8.4 U
Phenols in µg/kg						
Phenol	420	38 U	19 U	35	39 U	22
2-Methylphenol	63	38 U	19 U	20 U	39 U	19 U
4-Methylphenol	670	38 U	19 U	38	39 U	21
2,4-Dimethylphenol	29	*38 U*	19 U	20 U	*39 U*	19 U
Pentachlorophenol	360	190 U	510	98 U	190 U	95 U
LPAHs in µg/kg						
2-Methylnaphthalene	670	49	55	170	70	110
Acenaphthene	500	180	500	310	390	320
Acenaphthylene	1300	68	51	190	100	74
Anthracene	960	760	1300	1400	890	900
Fluorene	540	200	320	500	500	370
Naphthalene	2100	58	40	170	91	100
Phenanthrene	1500	1800	2900	2900	2000	2600
LPAHs	5200	3115	5166	5640	4041	4474
HPAHs in µg/kg						
Pyrene	3300	5300	5100	12000	3000	4500
Benzo(a)anthracene	1600	1800	2400	5200	1800	2300
Chrysene	2800	2400	3000	7700	1900	3200

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Table B-3 - Analytical Results for Bank Samples

Sample ID		IY-B-01	IY-B-02	IY-B-03	IY-B-04	IY-B-80
Sampling Date		1/19/98	1/19/98	1/21/98	1/21/98	1/21/98
Depth Interval	SQO	0 to 10 cm	0 to 10 cm	0 to 10 cm	0 to 10 cm	0 to 10 cm
						Dup of IY-B-04
Benzo(b)fluoranthene		2200	2200	6500	2300	2400
Benzo(k)fluoranthene		2400	2000	5600	980	2300
Total Benzofluoranthenes	3600	4600	4200	12100	3280	4700
Benzo(a)pyrene	1600	2100	1800	5700	1500	2200
Fluoranthene	2500	3000	8600	11000	6400	5800
Indeno(1,2,3-cd)pyrene	690	890	710	2000	670	780
Dibenz(a,h)anthracene	230	490	350	1100	180 M	350
Benzo(g,h,i)perylene	720	680	500	1200	520	580
HPAHs	17000	21260	26660	58000	19250	24410
Chlorinated Aromatics in µg/kg						
1,3-Dichlorobenzene	170	38 U	19 U	20 U	39 U	19 U
1,4-Dichlorobenzene	110	38 U	19 U	20 U	39 U	19 U
1,2-Dichlorobenzene	50	38 U	19 U	20 U	39 U	19 U
1,2,4-Trichlorobenzene	51	39	19 U	20 U	39 U	19 U
Hexachlorobenzene	22	*38 U*	23	7.3	2 UJ	11
Chlorinated Aliphatics in µg/kg						
Hexachlorobutadiene	11	*38 U*	*19 U*	9.5 U	5.4 UJ	8.6 U
Phthalates in µg/kg						
Dimethylphthalate	160	440	19 U	20 U	39 U	19 U
Diethylphthalate	200	38 U	19 U	20 U	39 U	19 U
Di-n-butylphthalate	1400	42	36	88	79	35
Butylbenzylphthalate	900	74	63	20 U	50 M	19 U
Bis(2-Ethylhexyl)phthalate	1300	1000	400	1200	1700	980
Di-n-octylphthalate	6200	38 U	19 U	20 U	39 U	19 U
Other Organic Compounds						
Benzyl Alcohol	73	38 U	19 U	20 U	39 U	19 U
Benzoic Acid	650	380 U	190 U	200 U	390 U	190 U
Dibenzofuran	540	100	170	220	140	160
N-Nitrosodiphenylamine	28	*38 U*	19 U	20 U	*39 U*	19 U
Hexachloroethane		38 U	19 U	20 U	39 U	19 U

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Table B-3 - Analytical Results for Bank Samples

Sample ID		IY-B-05	IY-B-06	IY-B-07	IY-B-08	IY-B-09
Sampling Date		1/21/98	1/20/98	1/20/98	1/20/98	1/20/98
Depth Interval	SQO	0 to 10 cm	0 to 10 cm	0 to 10 cm	0 to 10 cm	0 to 10 cm
Conventionals in %						
Total Organic Carbon		2.4	1.7	2.1	2.5	1.6
Total Solids		58	68.2	64.6	50.1	66
Metals in mg/kg						
Arsenic	57	27.3 J	56.3	28.3	20.7	$\boxed{116}$
Cadmium	5.1	0.88 U	0.73 U	0.78 U	0.89 U	0.74 U
Copper	390	229 J	$\boxed{1700}$ J	$\boxed{948}$ J	$\boxed{572}$ J	$\boxed{608}$ J
Lead	450	252 J	65.6 J	122 J	95.4 J	246 J
Mercury	0.59	0.42	0.11 J	0.55	0.19	0.25
Zinc	410	$\boxed{450}$ J	$\boxed{827}$ J	$\boxed{563}$ J	$\boxed{443}$ J	$\boxed{759}$ J
Pesticide/PCBs in µg/kg						
Aroclor 1016		690 U	19 U	18 U	20 U	20 U
Aroclor 1221		1400 U	39 U	36 U	40 U	39 U
Aroclor 1232		690 U	19 U	18 U	20 U	20 U
Aroclor 1242		690 U	19 U	18 U	20 U	20 U
Aroclor 1248		690 U	19 U	18 U	20 U	20 U
Aroclor 1254		690 U	190	18 U	20 U	20 U
Aroclor 1260		7300	910	110	120 U	290
Total PCBs	300	$\boxed{7300}$	$\boxed{1100}$	110	120 U	290
4,4'-DDE	9	*69 U*	1.9 U	1.8 U	2 U	2 U
4,4'-DDD	16	*69 U*	2.8 U	2.8	8.4	3.2
4,4'-DDT	34	*69 U*	17 U	5.1 U	11 U	6.6 U
Phenols in µg/kg						
Phenol	420	28	110	89	28	87
2-Methylphenol	63	19 U	39 U	19 U	20 U	20 U
4-Methylphenol	670	19 U	77	27	22	20 U
2,4-Dimethylphenol	29	19 U	*39 U*	19 U	20 U	20 U
Pentachlorophenol	360	95 U	200 U	96 U	99 U	99 U
LPAHs in µg/kg						
2-Methylnaphthalene	670	100	120	60	84	90
Acenaphthene	500	190	460	190	160	140
Acenaphthylene	1300	120	74	36	44	30
Anthracene	960	790	860	390	630	430
Fluorene	540	270	470	220	220	160
Naphthalene	2100	82	160	58	66	90
Phenanthrene	1500	$\boxed{1800}$	$\boxed{2400}$	1300	$\boxed{2000}$	1300
LPAHs	5200	3352	4544	2254	3204	2240
HPAHs in µg/kg						
Pyrene	3300	$\boxed{5700}$	3100	2800	$\boxed{3400}$	2600
Benzo(a)anthracene	1600	$\boxed{2300}$	$\boxed{2300}$	1100	1400	890
Chrysene	2800	$\boxed{3600}$	1800	2100	2400	1200

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Table B-3 - Analytical Results for Bank Samples

Sample ID		IY-B-05	IY-B-06	IY-B-07	IY-B-08	IY-B-09
Sampling Date		1/21/98	1/20/98	1/20/98	1/20/98	1/20/98
Depth Interval	SQO	0 to 10 cm	0 to 10 cm	0 to 10 cm	0 to 10 cm	0 to 10 cm
Benzo(b)fluoranthene		2800	1900	1100	1400	920
Benzo(k)fluoranthene		2300	1100	1200	1600	1400
Total Benzofluoranthenes	3600	5100	3000	2300	3000	2320
Benzo(a)pyrene	1600	2200	1400	1200	1500	1200
Fluoranthene	2500	5500	6800	3500	4100	2800
Indeno(1,2,3-cd)pyrene	690	1000	790	610	660	540
Dibenz(a,h)anthracene	230	580	240	310	330	280
Benzo(g,h,i)perylene	720	770	510	460	470	410
HPAHs	17000	26750	19940	14380	17260	12240
Chlorinated Aromatics in µg/kg						
1,3-Dichlorobenzene	170	19 U	39 U	19 U	20 U	20 U
1,4-Dichlorobenzene	110	19 U	39 U	19 U	20 U	20 U
1,2-Dichlorobenzene	50	19 U	39 U	19 U	20 U	20 U
1,2,4-Trichlorobenzene	51	19 U	39 U	19 U	20 U	20 U
Hexachlorobenzene	22	19 U	0.97 U	1.8	2	1
Chlorinated Aliphatics in µg/kg						
Hexachlorobutadiene	11	*19 U*	7.5 U	7.8 U	3.3 U	3 U
Phthalates in µg/kg						
Dimethylphthalate	160	20	44 M	19 U	20 U	20 U
Diethylphthalate	200	19 U	39 U	19 U	20 U	20 U
Di-n-butylphthalate	1400	30	100 M	46	69	26
Butylbenzylphthalate	900	32	39 U	36	81	36
Bis(2-Ethylhexyl)phthalate	1300	810	730	700	1100	460
Di-n-octylphthalate	6200	19 U	39 U	81	53	31
Other Organic Compounds						
Benzyl Alcohol	73	19 U	170	19 U	36	20 U
Benzoic Acid	650	190 U	390 U	190 U	200 U	200 U
Dibenzofuran	540	110	290	130	98	85
N-Nitrosodiphenylamine	28	19 U	*39 U*	19 U	20 U	20 U
Hexachloroethane		19 U	39 U	19 U	20 U	20 U

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Table B-3 - Analytical Results for Bank Samples

Sample ID		IY-B-10	IY-B-11
Sampling Date		1/20/98	1/20/98
Depth Interval	SQO	0 to 10 cm	0 to 10 cm
Conventionals in %			
Total Organic Carbon		1.2	0.78
Total Solids		72.2	63.7
Metals in mg/kg			
Arsenic	57	33.7	23.5
Cadmium	5.1	0.7 U	0.66 U
Copper	390	$\boxed{625}$ J	329 J
Lead	450	175 J	59.4 J
Mercury	0.59	0.35	0.06 J
Zinc	410	399 J	296 J
Pesticide/PCBs in µg/kg			
Aroclor 1016		18 U	19 U
Aroclor 1221		36 U	37 U
Aroclor 1232		18 U	19 U
Aroclor 1242		18 U	19 U
Aroclor 1248		18 U	19 U
Aroclor 1254		18 U	30 U
Aroclor 1260		73 U	26 U
Total PCBs	300	73 U	37 U
4,4'-DDE	9	1.8 U	1.9 U
4,4'-DDD	16	1.8 U	1.9 U
4,4'-DDT	34	1.6 U	1.9 U
Phenols in µg/kg			
Phenol	420	37	19 U
2-Methylphenol	63	20 U	19 U
4-Methylphenol	670	20 U	19 U
2,4-Dimethylphenol	29	20 U	19 U
Pentachlorophenol	360	98 U	93 U
LPAHs in µg/kg			
2-Methylnaphthalene	670	71	19 U
Acenaphthene	500	170	31
Acenaphthylene	1300	41	19 U
Anthracene	960	530	150
Fluorene	540	230	44
Naphthalene	2100	86	56
Phenanthrene	1500	$\boxed{3000}$	350
LPAHs	5200	4128	631
HPAHs in µg/kg			
Pyrene	3300	$\boxed{5700}$	950
Benzo(a)anthracene	1600	$\boxed{2000}$	690
Chrysene	2800	$\boxed{3000}$	680

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Table B-3 - Analytical Results for Bank Samples

Sample ID		IY-B-10	IY-B-11
Sampling Date		1/20/98	1/20/98
Depth Interval	SQO	0 to 10 cm	0 to 10 cm
Benzo(b)fluoranthene		2300	860
Benzo(k)fluoranthene		1600	690
Total Benzofluoranthenes	3600	3900	1550
Benzo(a)pyrene	1600	1800	850
Fluoranthene	2500	10000	1100
Indeno(1,2,3-cd)pyrene	690	650	570
Dibenz(a,h)anthracene	230	360	140
Benzo(g,h,i)perylene	720	480	370
HPAHs	17000	27890	6900
Chlorinated Aromatics in µg/kg			
1,3-Dichlorobenzene	170	20 U	19 U
1,4-Dichlorobenzene	110	20 U	19 U
1,2-Dichlorobenzene	50	20 U	19 U
1,2,4-Trichlorobenzene	51	20 U	19 U
Hexachlorobenzene	22	0.61 J	0.93 U
Chlorinated Aliphatics in µg/kg			
Hexachlorobutadiene	11	1.6 U	1.3
Phthalates in µg/kg			
Dimethylphthalate	160	30	19 U
Diethylphthalate	200	20 U	19 U
Di-n-butylphthalate	1400	26	19 U
Butylbenzylphthalate	900	27	19 U
Bis(2-Ethylhexyl)phthalate	1300	350	150
Di-n-octylphthalate	6200	27	19 U
Other Organic Compounds			
Benzyl Alcohol	73	20 U	19 U
Benzoic Acid	650	200 U	190 U
Dibenzofuran	540	110	21
N-Nitrosodiphenylamine	28	20 U	19 U
Hexachloroethane		20 U	19 U

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Table B-4 - Analytical Results for Upper Bank Samples

Sample ID		IY-UB-01	IY-UB-02	IY-UB-03	IY-UB-04	IY-UB-05
Sampling Date		1/22/98	1/22/98	1/22/98	1/22/98	1/22/98
Depth Interval	SQO	0 to 10 cm	0 to 10 cm	0 to 10 cm	0 to 10 cm	0 to 10 cm
Conventionals in %						
Total Organic Carbon		3.2	5.5	2	2.3	2.3
Total Solids		82.5	78.2	76.6	77.4	74.9
Metals in mg/kg						
Arsenic	57	48.4 J	37.1 J	29.6 J	35.2 J	65.8 J
Cadmium	5.1	0.6 U	0.63 U	0.67 U	0.65 U	0.69 J
Copper	390	382 J	662 J	286 J	324 J	1340 J
Lead	450	829 J	207 J	181 J	211 J	208 J
Mercury	0.59	1.1	0.49	0.42	0.54	0.18 J
Zinc	410	1470 J	1600 J	507 J	504 J	3480 J
Pesticide/PCBs in µg/kg						
Aroclor 1016		990 U	1000 U	20 UJ	19 U	19 U
Aroclor 1221		2000 U	2000 U	39 UJ	37 U	37 U
Aroclor 1232		990 U	1000 U	20 UJ	19 U	19 U
Aroclor 1242		990 U	1000 U	20 UJ	19 U	19 U
Aroclor 1248		990 U	1000 U	20 UJ	19 U	19 U
Aroclor 1254		990 U	1000 U	20 UJ	19 U	19 U
Aroclor 1260		32000	30000	150 J	170	89
Total PCBs	300	32000	30000	150 J	170	89
4,4'-DDE	9	*99 U*	*100 U*	3.7 UJ	1.9 U	2.7 U
4,4'-DDD	16	*99 U*	*100 U*	7.3 UJ	11 U	2.7 U
4,4'-DDT	34	*580 U*	*590 U*	24 J	37	9.8
Phenols in µg/kg						
Phenol	420	77 U	190 U	39 U	45	67
2-Methylphenol	63	77 U	190 U	39 U	19 U	37 U
4-Methylphenol	670	77 U	190 U	39 U	44 M	56 M
2,4-Dimethylphenol	29	*77 U*	*190 U*	*39 U*	19 U	*37 U*
Pentachlorophenol	360	*390 U*	*970 U*	200 U	93 U	190 U
LPAHs in µg/kg						
2-Methylnaphthalene	670	77 U	190 U	240	62	37 U
Acenaphthene	500	200	270	340	130	68
Acenaphthylene	1300	120	190 U	40	62	43
Anthracene	960	700	1000	730	420	220 M
Fluorene	540	150	300	420	140	67
Naphthalene	2100	77 U	190 U	170	62	46
Phenanthrene	1500	1700	3700	1800	1000	640
LPAHs	5200	2870	5270	3740	1876	1084
HPAHs in µg/kg						
Pyrene	3300	2300	4100	1800	1200	880
Benzo(a)anthracene	1600	1400	2000	1200	990	520
Chrysene	2800	2100	2600	1600	1000	790

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Table B-4 - Analytical Results for Upper Bank Samples

Sample ID		IY-UB-01	IY-UB-02	IY-UB-03	IY-UB-04	IY-UB-05
Sampling Date		1/22/98	1/22/98	1/22/98	1/22/98	1/22/98
Depth Interval	SQO	0 to 10 cm	0 to 10 cm	0 to 10 cm	0 to 10 cm	0 to 10 cm
Benzo(b)fluoranthene		1100	1600	780	1100	360
Benzo(k)fluoranthene		1500	1300	970	670	780
Total Benzofluoranthenes	3600	2600	2900	1750	1770	1140
Benzo(a)pyrene	1600	1100	1200	1000	990	500
Fluoranthene	2500	4200	3800	1800	1300	1200
Indeno(1,2,3-cd)pyrene	690	720	620	500	440	420
Dibenz(a,h)anthracene	230	160 M	190 U	160 M	240 M	100 M
Benzo(g,h,i)perylene	720	520	730 M	330	310	280
HPAHs	17000	15100	17950	10140	8240	5830
Chlorinated Aromatics in µg/kg						
1,3-Dichlorobenzene	170	77 U	*190 U*	39 U	19 U	37 U
1,4-Dichlorobenzene	110	77 U	*190 U*	39 U	19 U	37 U
1,2-Dichlorobenzene	50	*77 U*	*190 U*	39 U	19 U	37 U
1,2,4-Trichlorobenzene	51	*77 U*	*190 U*	39 U	19 U	37 U
Hexachlorobenzene	22	*50 U*	*51 U*	0.98 UJ	13	0.93 U
Chlorinated Aliphatics in µg/kg						
Hexachlorobutadiene	11	*50 U*	*51 U*	3.6 UJ	9.5 U	1.6 U
Phthalates in µg/kg						
Dimethylphthalate	160	77 U	1200	39 U	19 U	37 U
Diethylphthalate	200	77 U	190 U	39 U	19 U	37 U
Di-n-butylphthalate	1400	77 U	190 U	39 U	59 M	70
Butylbenzylphthalate	900	77 U	190 U	39 U	28 M	40 M
Bis(2-Ethylhexyl)phthalate	1300	480	360	420	480	440
Di-n-octylphthalate	6200	77 U	190 U	39 U	19 M	50 M
Other Organic Compounds						
Benzyl Alcohol	73	*77 U*	*190 U*	39 U	19 U	37 U
Benzoic Acid	650	*770 U*	*1900 U*	390 U	190 U	370 U
Dibenzofuran	540	81	190 U	120	69	38
N-Nitrosodiphenylamine	28	*77 U*	*190 U*	*39 U*	19 U	*37 U*
Hexachloroethane		77 U	190 U	39 U	19 U	37 U

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Table B-4 - Analytical Results for Upper Bank Samples

Sample ID		IY-UB-06	IY-UB-10
Sampling Date		1/22/98	1/20/98
Depth Interval	SQO	0 to 10 cm	0 to 10 cm
Conventionals in %			
Total Organic Carbon		1.6	5
Total Solids		85	80.3
Metals in mg/kg			
Arsenic	57	41.8 J	62.3 J
Cadmium	5.1	0.58 U	0.65 U
Copper	390	1370 J	799 J
Lead	450	181 J	737 J
Mercury	0.59	0.18	0.7
Zinc	410	510 J	539 J
Pesticide/PCBs in µg/kg			
Aroclor 1016		19 UJ	19 U
Aroclor 1221		39 UJ	37 U
Aroclor 1232		19 UJ	19 U
Aroclor 1242		19 UJ	19 U
Aroclor 1248		19 UJ	19 U
Aroclor 1254		19 UJ	19 U
Aroclor 1260		55 J	35
Total PCBs	300	55 J	35
4,4'-DDE	9	1.9 UJ	1.9 U
4,4'-DDD	16	5.4 UJ	1.9 U
4,4'-DDT	34	26 J	6.2
Phenols in µg/kg			
Phenol	420	91	23 J
2-Methylphenol	63	39 U	37 U
4-Methylphenol	670	42	20 J
2,4-Dimethylphenol	29	*39 U*	*37 U*
Pentachlorophenol	360	190 U	190 U
LPAHs in µg/kg			
2-Methylnaphthalene	670	39 U	78
Acenaphthene	500	41	46 M
Acenaphthylene	1300	39 U	45
Anthracene	960	84 M	180 M
Fluorene	540	39 U	61
Naphthalene	2100	52	89
Phenanthrene	1500	390	510
LPAHs	5200	567	1009
HPAHs in µg/kg			
Pyrene	3300	440	580
Benzo(a)anthracene	1600	230	440
Chrysene	2800	340	690

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Table B-4 - Analytical Results for Upper Bank Samples

Sample ID		IY-UB-06	IY-UB-10
Sampling Date		1/22/98	1/20/98
Depth Interval	SQO	0 to 10 cm	0 to 10 cm
Benzo(b)fluoranthene		230	420
Benzo(k)fluoranthene		210 M	480
Total Benzofluoranthenes	3600	440	900
Benzo(a)pyrene	1600	230	470
Fluoranthene	2500	520	630
Indeno(1,2,3-cd)pyrene	690	200	340
Dibenz(a,h)anthracene	230	50 M	80 M
Benzo(g,h,i)perylene	720	200	300
HPAHs	17000	2650	4430
Chlorinated Aromatics in µg/kg			
1,3-Dichlorobenzene	170	39 U	37 U
1,4-Dichlorobenzene	110	39 U	37 U
1,2-Dichlorobenzene	50	39 U	37 U
1,2,4-Trichlorobenzene	51	39 U	37 U
Hexachlorobenzene	22	0.97 UJ	0.93 U
Chlorinated Aliphatics in µg/kg			
Hexachlorobutadiene	11	1.1 UJ	39
Phthalates in µg/kg			
Dimethylphthalate	160	39 U	37 U
Diethylphthalate	200	39 U	37 U
Di-n-butylphthalate	1400	76 M	91
Butylbenzylphthalate	900	39 U	37 U
Bis(2-Ethylhexyl)phthalate	1300	510	300
Di-n-octylphthalate	6200	39 U	37 U
Other Organic Compounds			
Benzyl Alcohol	73	39 U	37 U
Benzoic Acid	650	390 U	370 U
Dibenzofuran	540	39 U	46 M
N-Nitrosodiphenylamine	28	*39 U*	*37 U*
Hexachloroethane		39 U	37 U

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APPENDIX C
SEDIMENT CHARACTERIZATION AND PHYSICAL TESTING

APPENDIX C
SEDIMENT CHARACTERIZATION AND PHYSICAL TESTING

Sediment samples obtained from the Port of Tacoma Industrial Yard (Industrial Yard) during the Pre-Remedial Design Study field sampling activities were submitted to Hart Crowser Geotechnical Laboratory and Analytical Resources, Inc. for physical testing to evaluate the grain size distribution, Atterberg limits, and moisture content of the site sediments.

The following were performed on all or selected sediment samples:

- Visual Observations and Descriptions (see Appendix A);
- Grain Size Analysis;
- Total Solids Determination, and
- Atterberg Limits Determination.

The test procedures that were followed are outlined below.

C.1 Grain Size Analysis

Grain size distribution was analyzed on select samples from the bank and side slope areas representative of the range of sediment types observed in the field. Sieve analysis conducted in general accordance with PSEP protocols. Dry sieve analysis was used to determine particle size distribution greater than the U.S. No. 230 mesh sieve. Classifications were made in accordance with ASTM D 2487 of the Unified Soil Classification (USC) System as depicted on Figure C-1. The size distribution for particles smaller than the No. 230 mesh were determined by the pipet method. Percent fines (sum of clay and silt fractions) are defined as that fraction less than 74 µm. Only sediments containing a fine fraction greater than 4 percent were run through the pipet analysis.

Grain size data results are summarized in Table C-1. The results of the tests are graphically presented as curves on Figures C-2 through C-11, which plot percent finer by weight versus grain size.

C.2 Total Solids

Sediment total solids content was analyzed on all of the bank area and side slope area representative sediment samples submitted for chemical analysis. Total solids were determined using Standard Method 160.3.

Total solids results are summarized in Table C-2.

C.3 Atterberg Limits

Atterberg limits determinations were performed on select fine-grained sediment samples from the Industrial Yard. The liquid and plastic limits were determined in general accordance with ASTM D 4318-84. The results of the Atterberg Limit analyses and plasticity characteristics of the tested samples are presented on Figure C-12.

Table C-1 Summary of Grain Size Distribution

Sample ID	Percent Gravel	Percent Sand	Percent Silt	Percent Clay	Material Description
Bank					
IY-B-08	9	70	17	4	Slightly gravelly, silty SAND
IY-B-10	12	85	2	1	Slightly gravelly SAND
IY-B-06	5	78	11	6	Slightly clayey, slightly silty SAND
IY-B-02	35	60	3	2	Very gravelly SAND
Side slope					
IY-C-01-S1	1	33	48	18	Clayey, very sandy SILT
IY-C-02-S1	3	29	47	21	Clayey, sandy SILT
IY-C-05-S1	2	42	37	19	Clayey, very silty SAND
IY-C-06-S1	1	30	51	18	Clayey, sandy SILT
IY-C-06-S1 Duplicate	0	29	50	21	Clayey, sandy SILT
IY-C-06-S1 Triplicate	2	29	50	19	Clayey, sandy SILT

Table C-1

Table C-2- Moisture Content of Sediment Samples

Sample ID		Total Solids[1]	Percent Moisture[2]
Side Slope			
IY-S-01		47.1	52.9
IY-S-02		47.5	52.5
IY-S-03		45.4	54.6
IY-S-04		46.5	53.5
IY-S-06		46.6	53.4
IY-S-80	Dup	44.3	55.7
Subsurface			
IY-C-01-S1		45.9	54.1
IY-C-01-S2		57.2	42.8
IY-C-02-S1		46.7	53.3
IY-C-02-S2		48.7	51.3
IY-C-03-S1		47.8	52.2
IY-C-03-S2		55.5	44.5
IY-C-04-S1		47.5	52.5
IY-C-04-S2		47.2	52.8
IY-C-05-S1		51.5	48.5
IY-C-05-S2		49.5	50.5
IY-C-06-S1		47.5	52.5
IY-C-06-S2		50.1	49.9
Bank			
IY-B-01		59.6	40.4
IY-B-02		74.3	25.7
IY-B-03		51.4	48.6
IY-B-04		63.9	36.1
IY-B-05		58	42.0
IY-B-06		68.2	31.8
IY-B-07		64.6	35.4
IY-B-08		50.1	49.9
IY-B-09		66	34.0
IY-B-10		72.2	27.8
IY-B-11		63.7	36.3
IY-B-80	Dup	61.2	38.8
Upper Bank			
IY-UB-01		82.5	17.5
IY-UB-02		78.2	21.8
IY-UB-03		76.6	23.4
IY-UB-04		77.4	22.6
IY-UB-05		74.9	25.1
IY-UB-06		85	15.0
IY-UB-10		80.3	19.7

Notes:
1. In Percent
2. Calculated as 100 - percent total solids.

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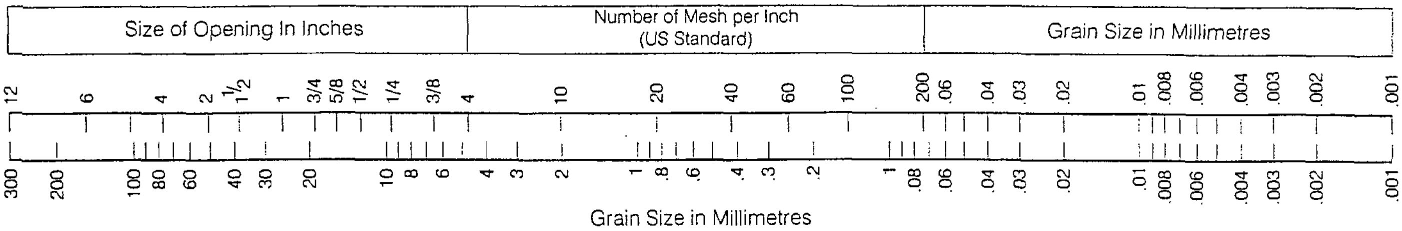
Unified Soil Classification (USC) System

Soil Grain Size



COBBLES	GRAVEL	SAND	SILT and CLAY
Coarse-Grained Soils			Fine-Grained Soils

Coarse-Grained Soils

G W	G P	G M	G C	S W	S P	S M	S C
Clean GRAVEL <5% fines		* GRAVEL with >12% fines		Clean SAND <5% fines		* SAND with >12% fines	
GRAVEL >50% coarse fraction larger than No. 4				SAND >50% coarse fraction smaller than No. 4			
Coarse-Grained Soils >50% larger than No. 200 sieve							

G W and S W $\left(\frac{D_{60}}{D_{10}}\right)$ >4 for G W, >6 for S W & $1 \leq \left(\frac{(D_{30})^2}{D_{10} \times D_{60}}\right) \leq 3$

G P and S P Clean GRAVEL or SAND not meeting requirements for G W and S W

G M and S M Atterberg limits below A line with PI <4

G C and S C Atterberg limits above A Line with PI >7

* Coarse-grained soils with percentage of fines between 5 and 12 are considered borderline cases required use of dual symbols.

D_{10}, D_{30}, and D_{60} are the particles diameter of which 10, 30, and 60 percent, respectively, of the soil weight are finer.

Fine-Grained Soils

M L	C L	O L	M H	C H	O H	Pt
SILT	CLAY	Organic	SILT	CLAY	Organic	Highly Organic Soils
Soils with Liquid Limit <50%			Soils with Liquid Limit >50%			
Fine-Grained Soils >50% smaller than No. 200 sieve						

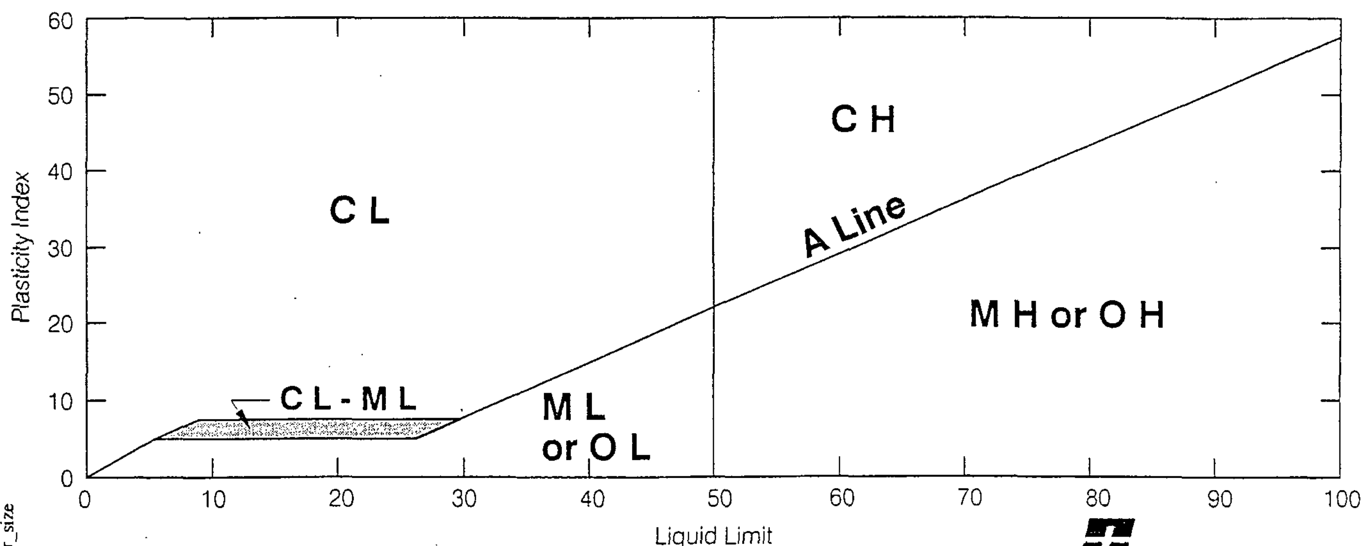


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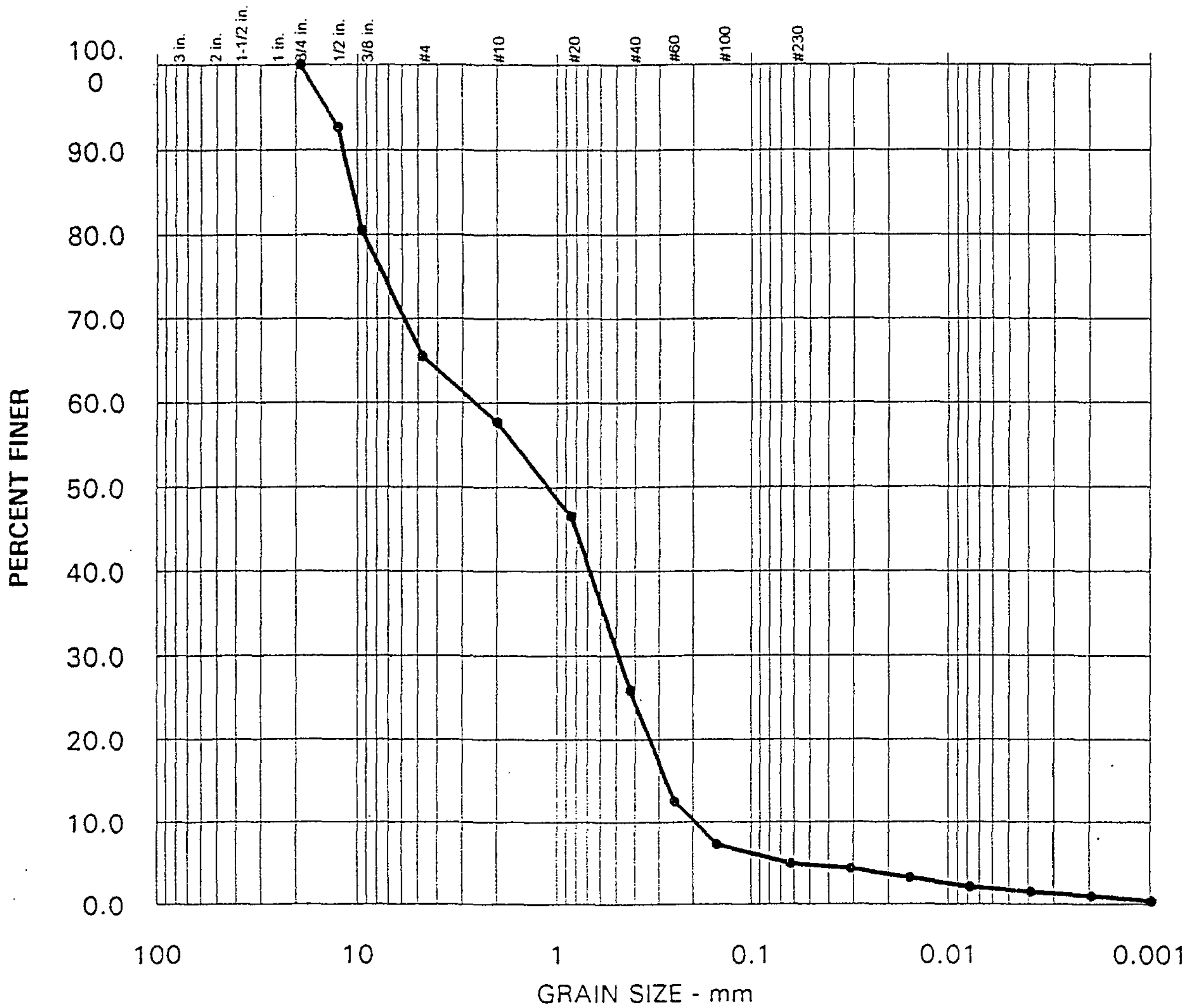
Figure C-1

SIEVE & PIPET ANALYSES TEST REPORT



% +75mm	% GRAVEL	% SAND	% SILT	% CLAY
	35%	60%	3%	2%

Exploration Number:	Sample Number:	Sample Depth	Sample Matrix:	Natural Moisture:
*	IY-B-02	*	Sediment	25%

MATERIAL DESCRIPTION
Very gravelly SAND

Remarks: Moisture content value is based on wet weight

Project: IY-Hylebos

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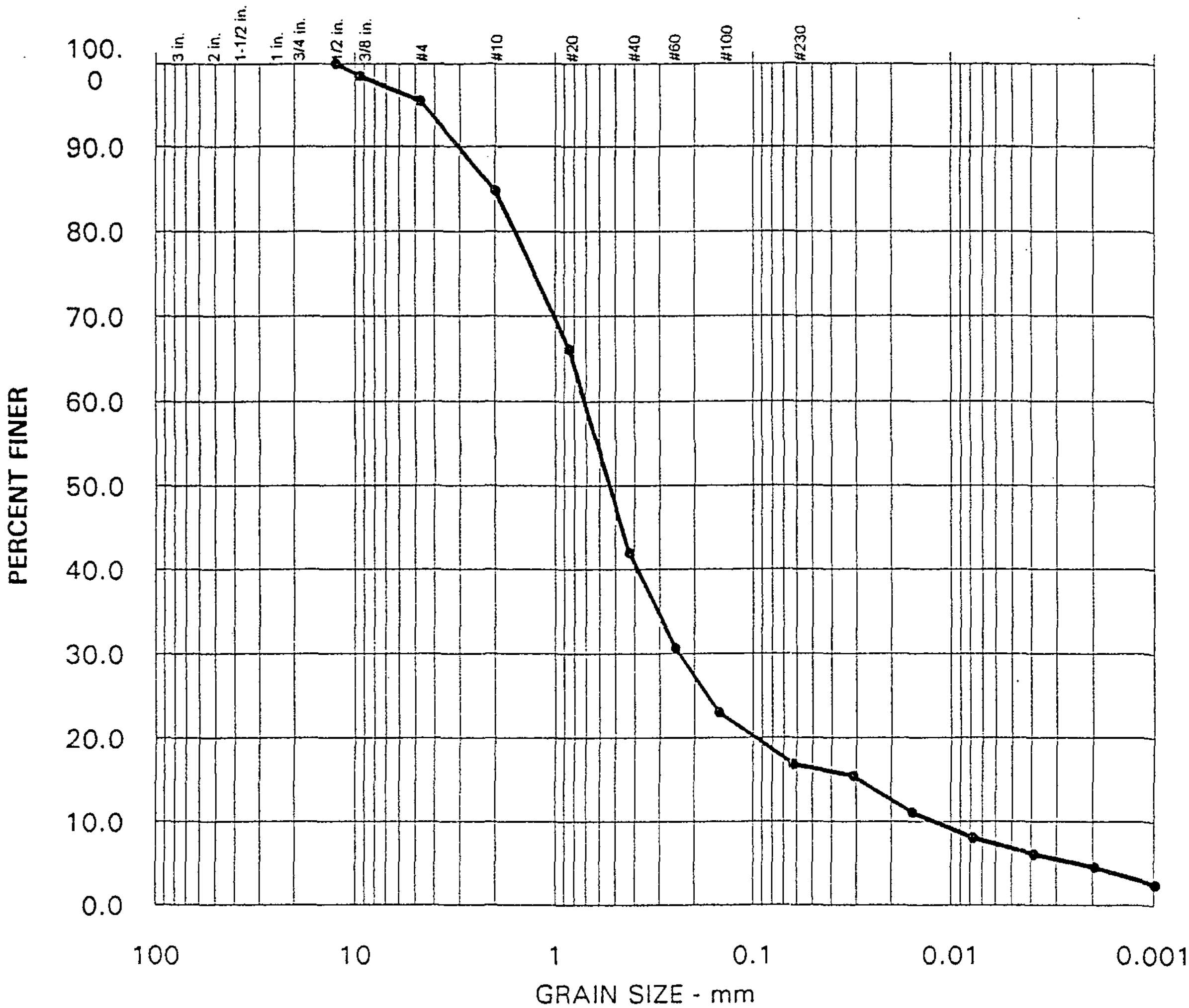
Figure C-2

SIEVE & PIPET ANALYSES TEST REPORT



% +75mm	% GRAVEL	% SAND	% SILT	% CLAY
	5%	78%	11%	6%

Exploration Number:	Sample Number:	Sample Depth	Sample Matrix:	Natural Moisture:
*	IY-B-06	*	Sediment	29%

	MATERIAL DESCRIPTION	
	Slightly clayey, slightly silty SAND	

Remarks: Moisture content value is based on wet weight

Project: IY-Hylebos

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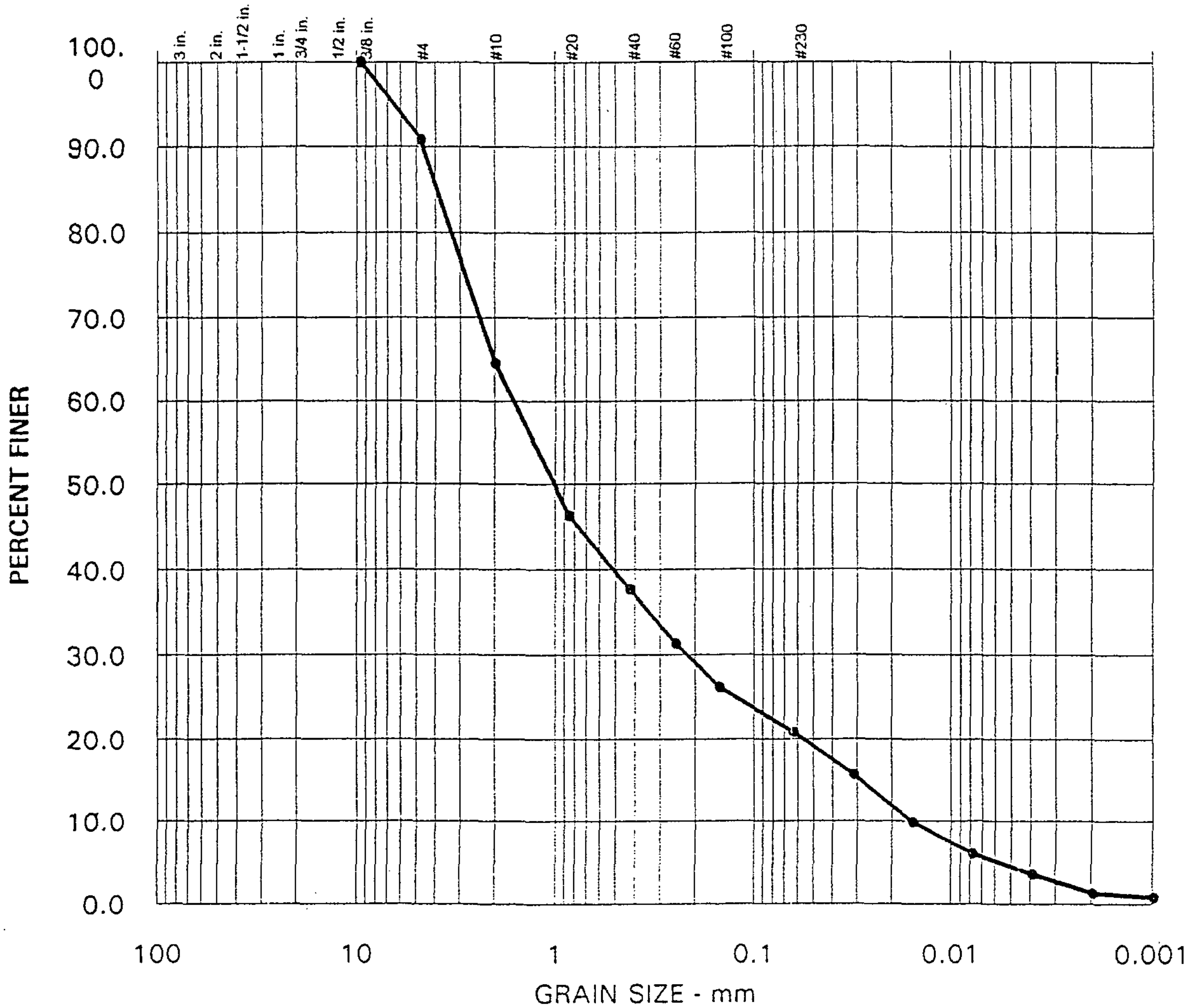
Figure C-3

SIEVE & PIPET ANALYSES TEST REPORT



% +75mm	% GRAVEL	% SAND	% SILT	% CLAY
	9%	70%	17%	4%

Exploration Number:	Sample Number:	Sample Depth	Sample Matrix:	Natural Moisture:
*	IY-B-08	*	Sediment	51%

MATERIAL DESCRIPTION
Slightly gravelly, silty SAND

Remarks: Moisture content value is based on wet weight

Project: IY-Hylebos

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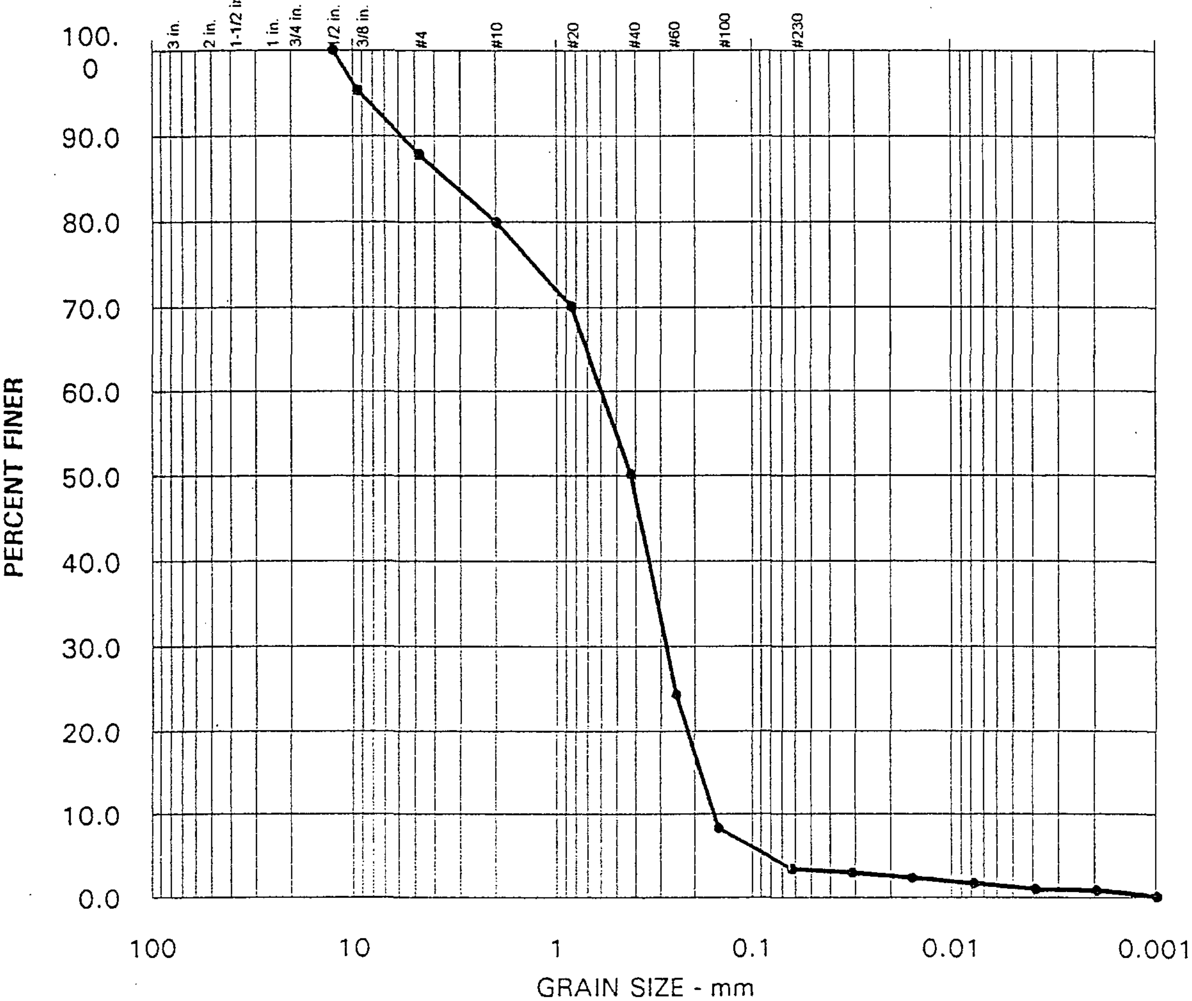
Figure C-4

SIEVE & PIPET ANALYSES TEST REPORT



% +75mm	% GRAVEL	% SAND	% SILT	% CLAY
	12%	85%	2%	1%

Exploration Number:	Sample Number:	Sample Depth	Sample Matrix:	Natural Moisture:
*	IY-B-10	*	Sediment	28%

	MATERIAL DESCRIPTION	
	Slightly gravelly SAND	

Remarks: Moisture content value is based on wet weight

Project: IY-Hylebos

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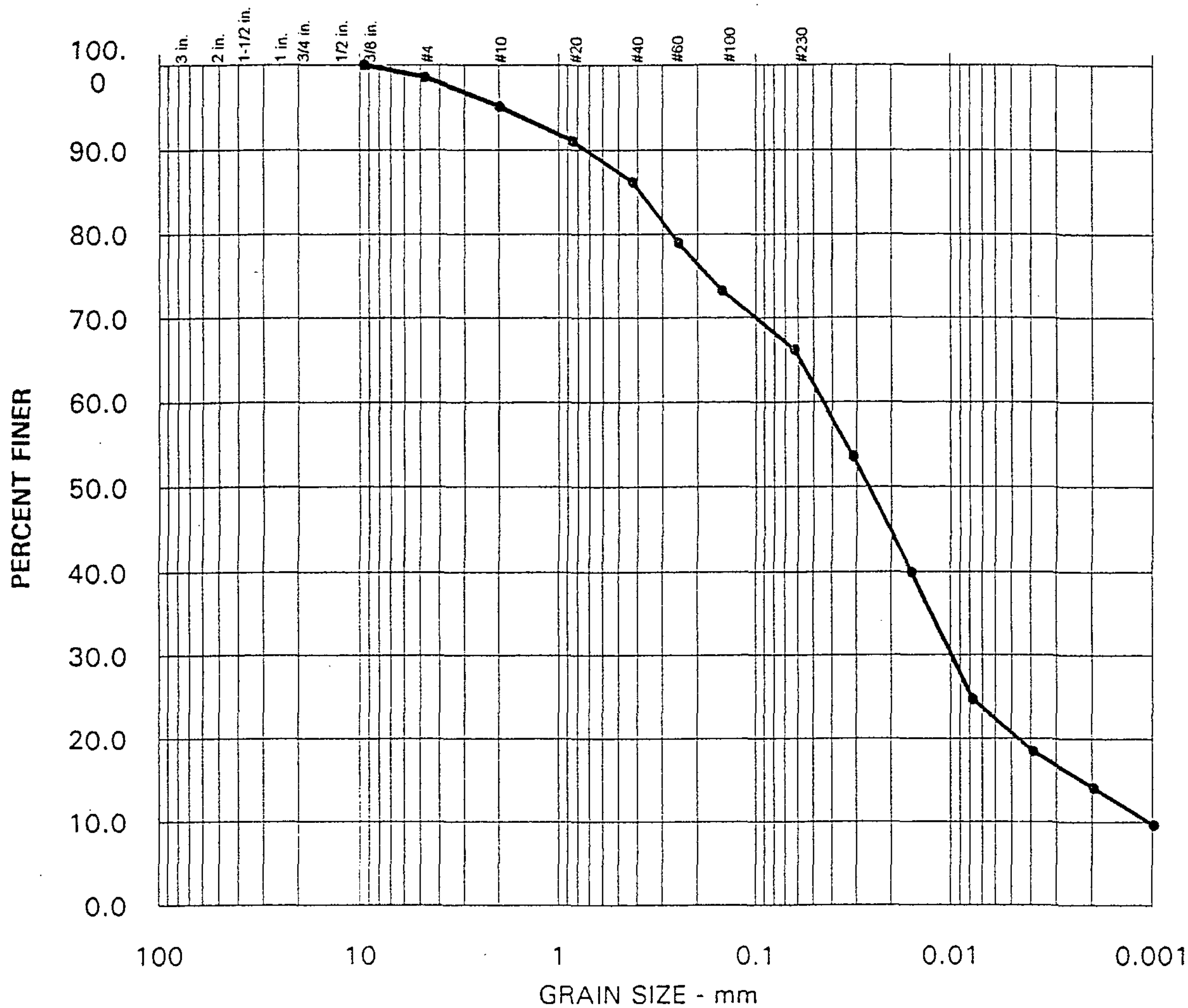
Figure C-5

SIEVE & PIPET ANALYSES TEST REPORT



% +75mm	% GRAVEL	% SAND	% SILT	% CLAY
	1%	33%	48%	18%

Exploration Number:	Sample Number:	Sample Depth	Sample Matrix:	Natural Moisture:
*	IY-C-01-S1	*	Sediment	53%

	MATERIAL DESCRIPTION	
	Clayey, very sandy SILT	

Remarks: Moisture content value is based on wet weight

Project: IY- Hylebos

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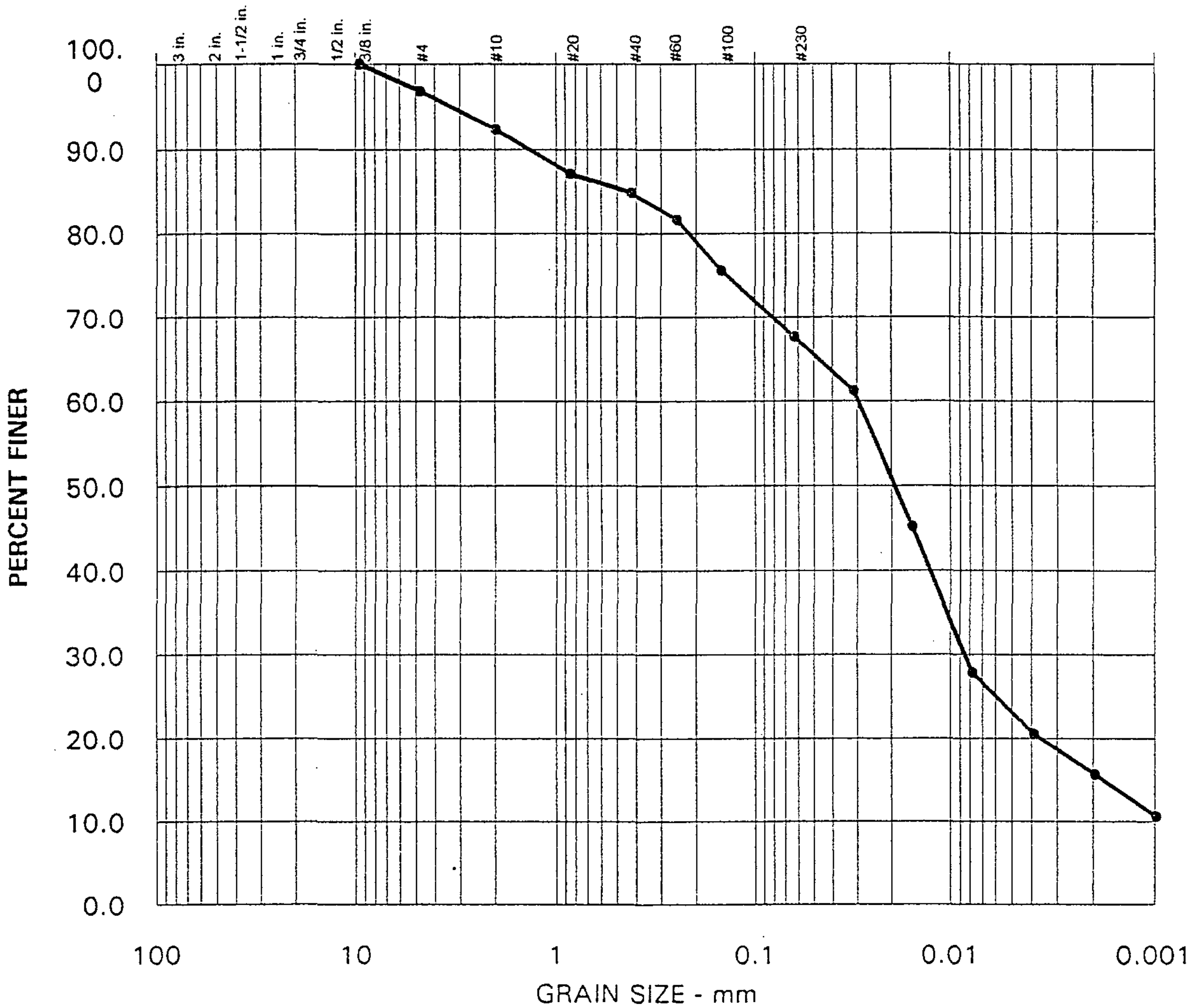
Figure *C–6*

SIEVE & PIPET ANALYSES TEST REPORT



% +75mm	% GRAVEL	% SAND	% SILT	% CLAY
	3%	29%	47%	21%

Exploration Number:	Sample Number:	Sample Depth	Sample Matrix:	Natural Moisture:
*	IY-C-02-S1	*	Sediment	54%

	MATERIAL DESCRIPTION	
	Clayey, sandy SILT	

Remarks: Moisture content value is based on wet weight

Project: IY- Hylebos

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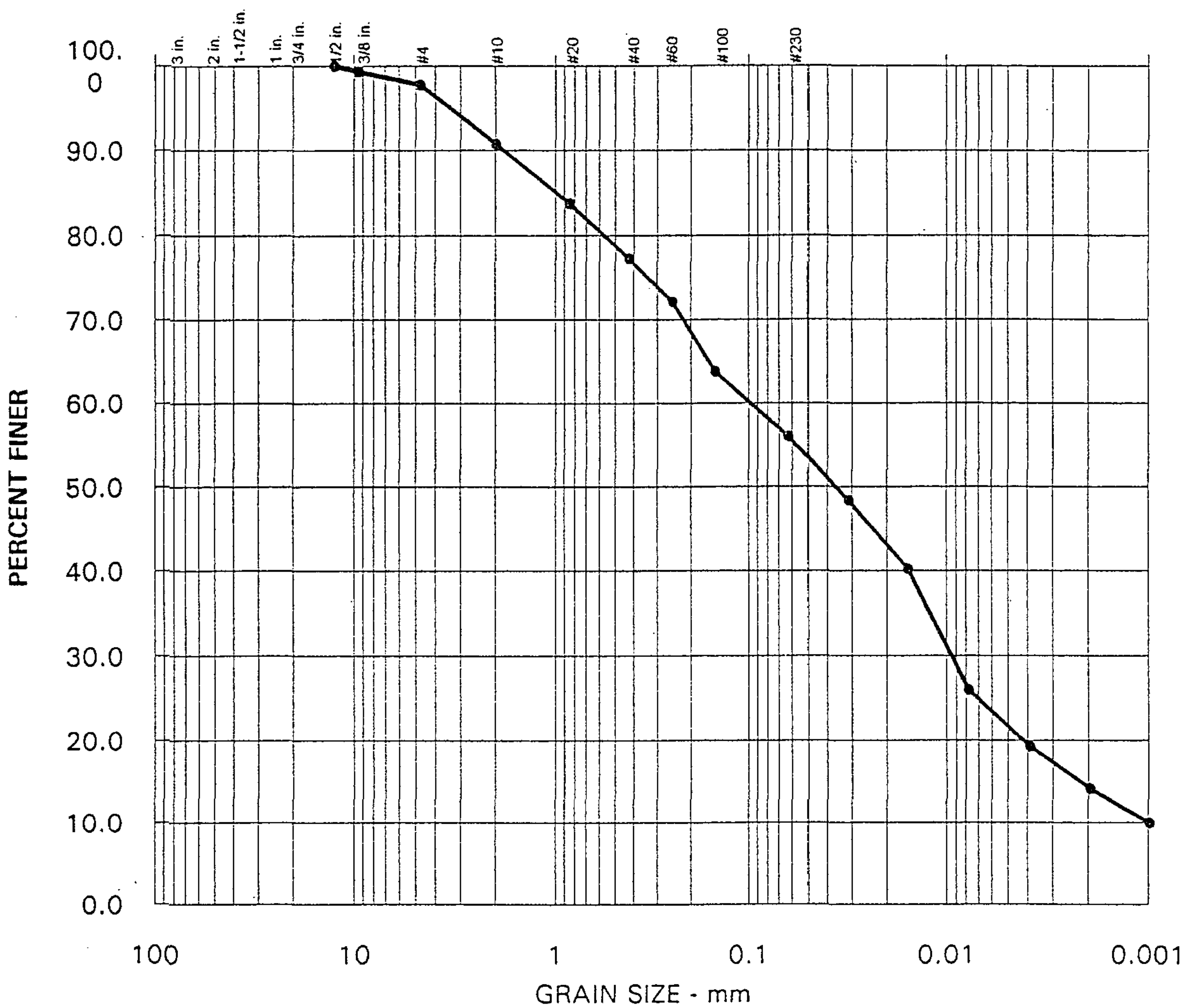
Figure C-7

SIEVE & PIPET ANALYSES TEST REPORT



% +75mm	% GRAVEL	% SAND	% SILT	% CLAY
	2%	42%	37%	19%

Exploration Number:	Sample Number:	Sample Depth	Sample Matrix:	Natural Moisture:
*	IY-C-05-S1	*	Sediment	49%

MATERIAL DESCRIPTION
Clayey, very silty SAND

Remarks: Moisture content value is based on wet weight

Project: IY-Hylebos

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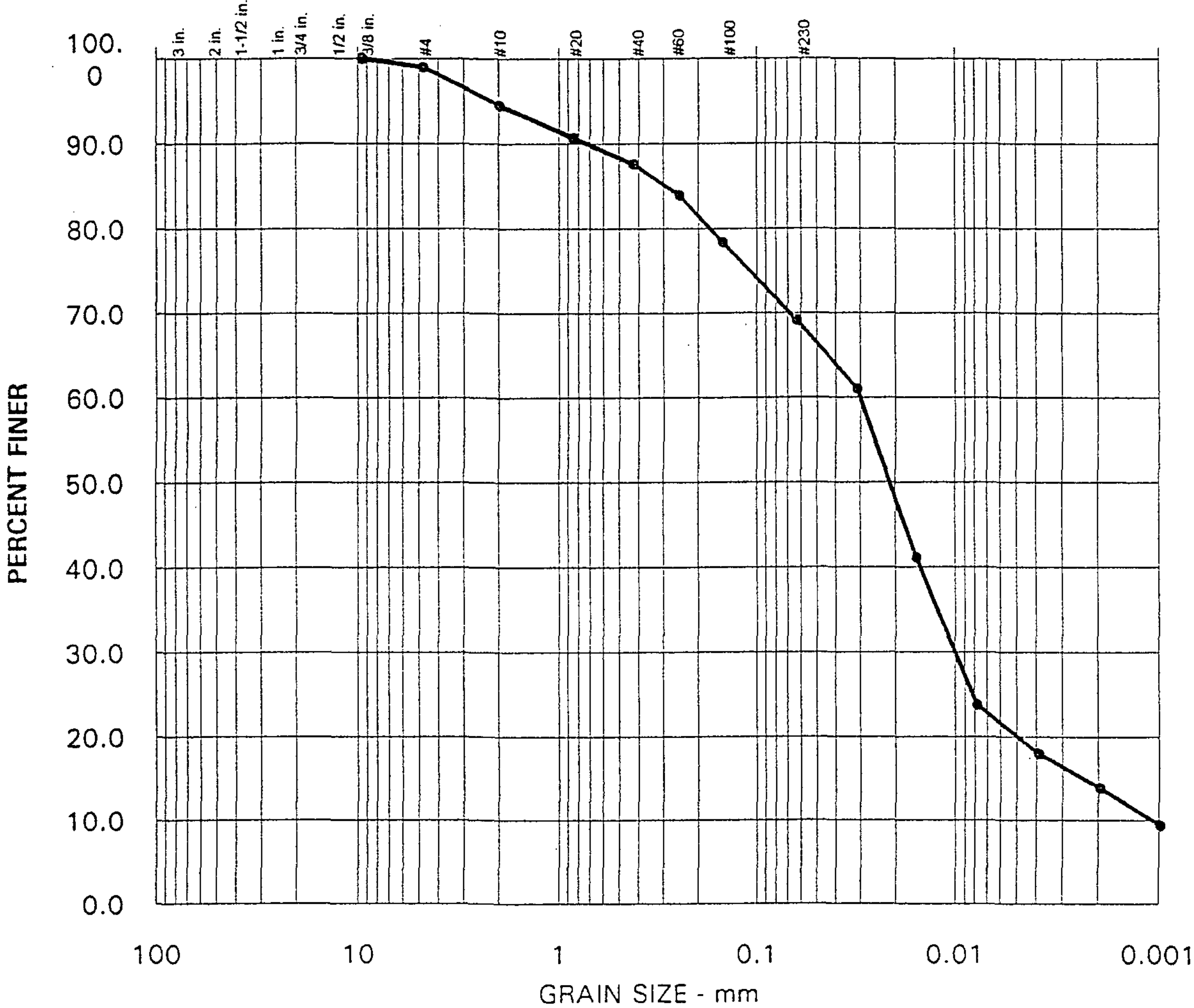
Figure C-8

SIEVE & PIPET ANALYSES TEST REPORT



% +75mm	% GRAVEL	% SAND	% SILT	% CLAY
	1%	30%	51%	18%

Exploration Number:	Sample Number:	Sample Depth	Sample Matrix:	Natural Moisture:
*	IY-C-06-S1 (A)	*	Sediment	54%

	MATERIAL DESCRIPTION	
	Clayey, sandy SILT	

Remarks: Moisture content value is based on wet weight

Project: IY-Hylebos

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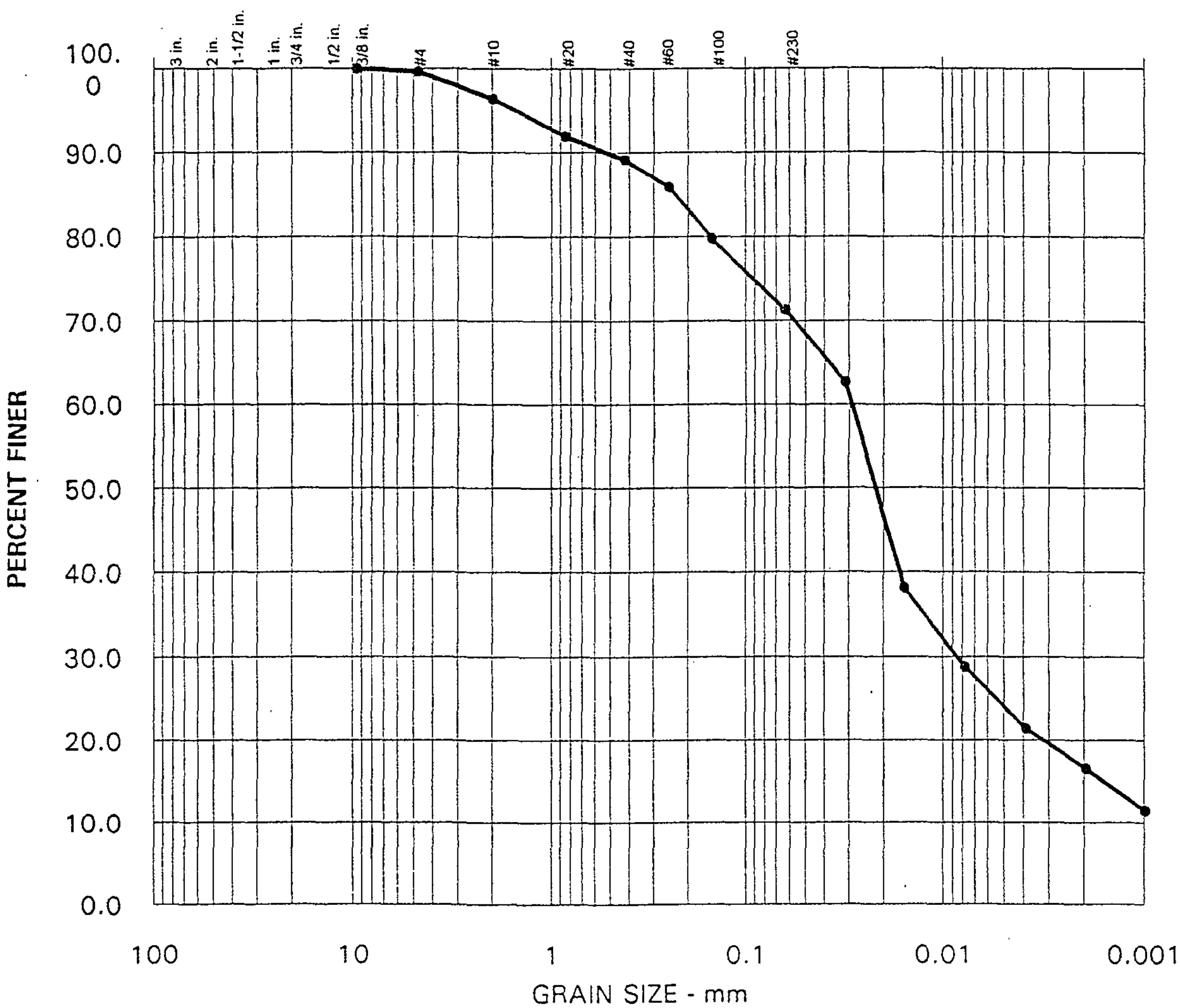
Figure C-9

SIEVE & PIPET ANALYSES TEST REPORT



% +75mm	% GRAVEL	% SAND	% SILT	% CLAY
	0%	29%	50%	21%

Exploration Number:	Sample Number:	Sample Depth	Sample Matrix:	Natural Moisture:
*	IY-C-06-S1 (B) Duplicate	*	Sediment	54%

	MATERIAL DESCRIPTION	
	Clayey, sandy SILT	

Remarks: Moisture content value is based on wet weight

Project: IY-Hylebos

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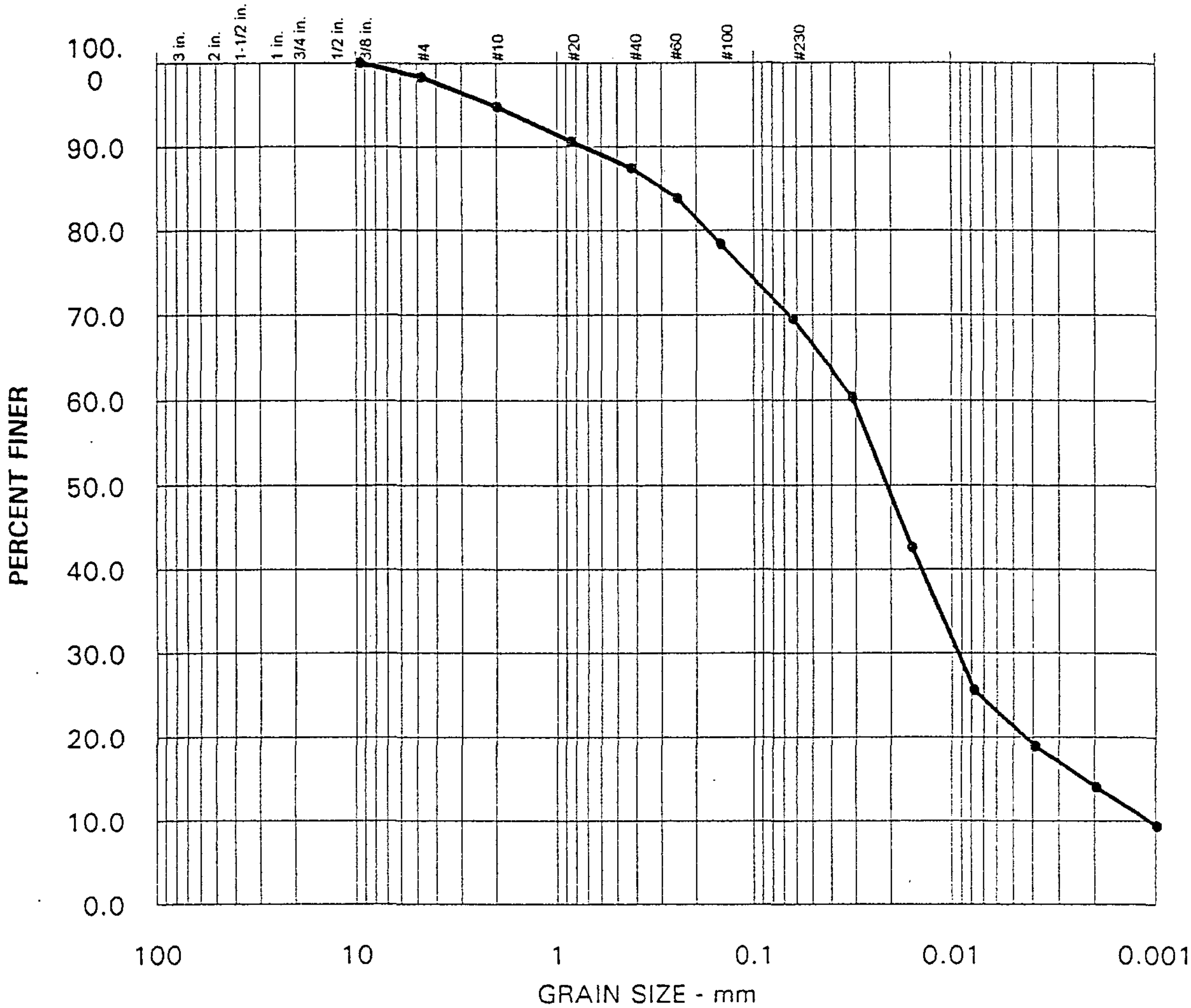
Figure C-10

SIEVE & PIPET ANALYSES TEST REPORT



% +75mm	% GRAVEL	% SAND	% SILT	% CLAY
	2%	29%	50%	19%

Exploration Number:	Sample Number:	Sample Depth	Sample Matrix:	Natural Moisture:
*	IY-C-06-S1 (C) Triplicate	*	Sediment	54%

	MATERIAL DESCRIPTION	
	Clayey, sandy SILT	

Remarks: Moisture content value is based on wet weight

Project: IY-Hylebos

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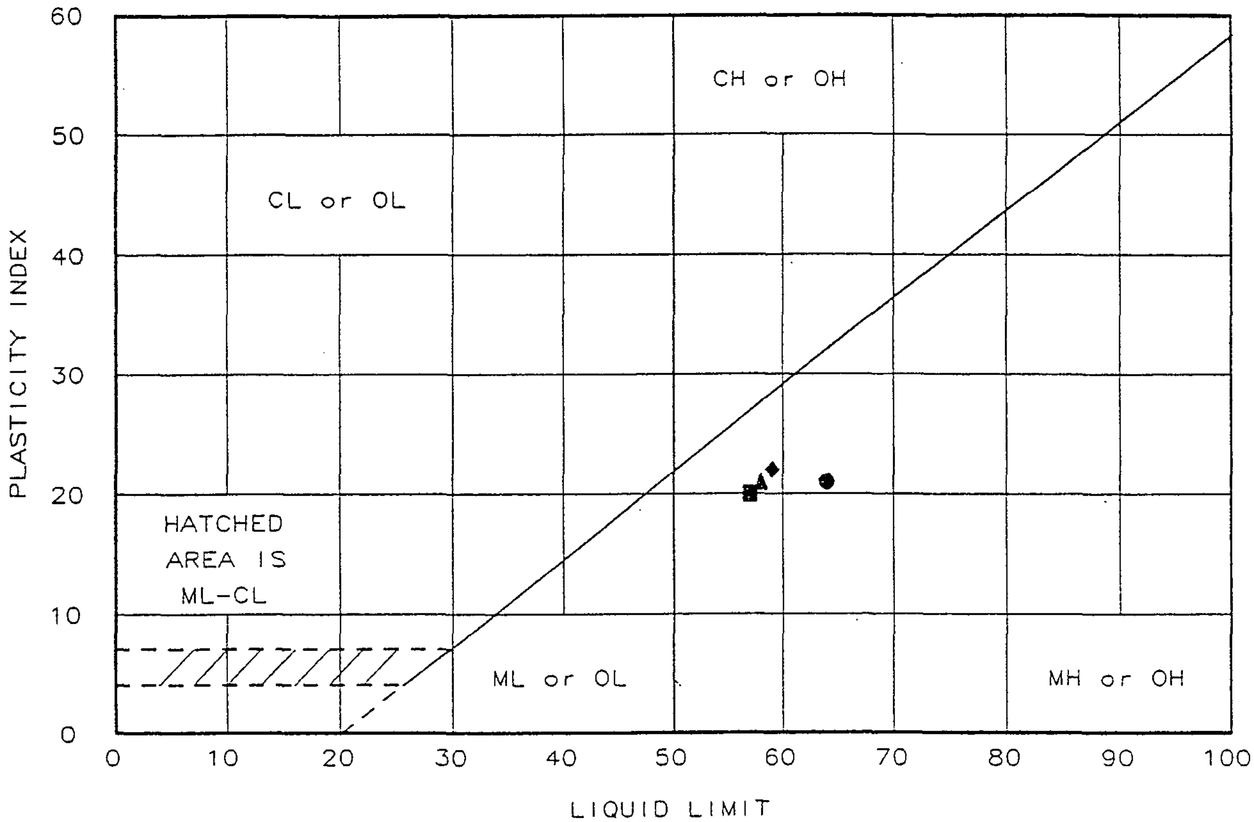
Figure *C-11*

LIQUID AND PLASTIC LIMITS TEST REPORT



	Location + Description	LL	PL	PI	-200	ASTM D 2487-90
●	IY-C-01-S1	64	43	21		
▲	IY-C-02-S1	58	37	21		
■	IY-C-05-S1	57	37	20		
◆	IY-C-06-S1	59	37	22		

Remarks:

Project: IY-Hylebos

Client:

Location:

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Figure C-12